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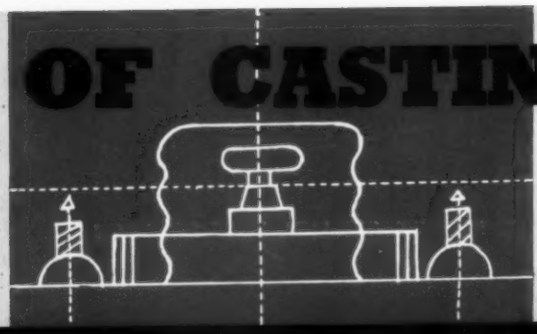

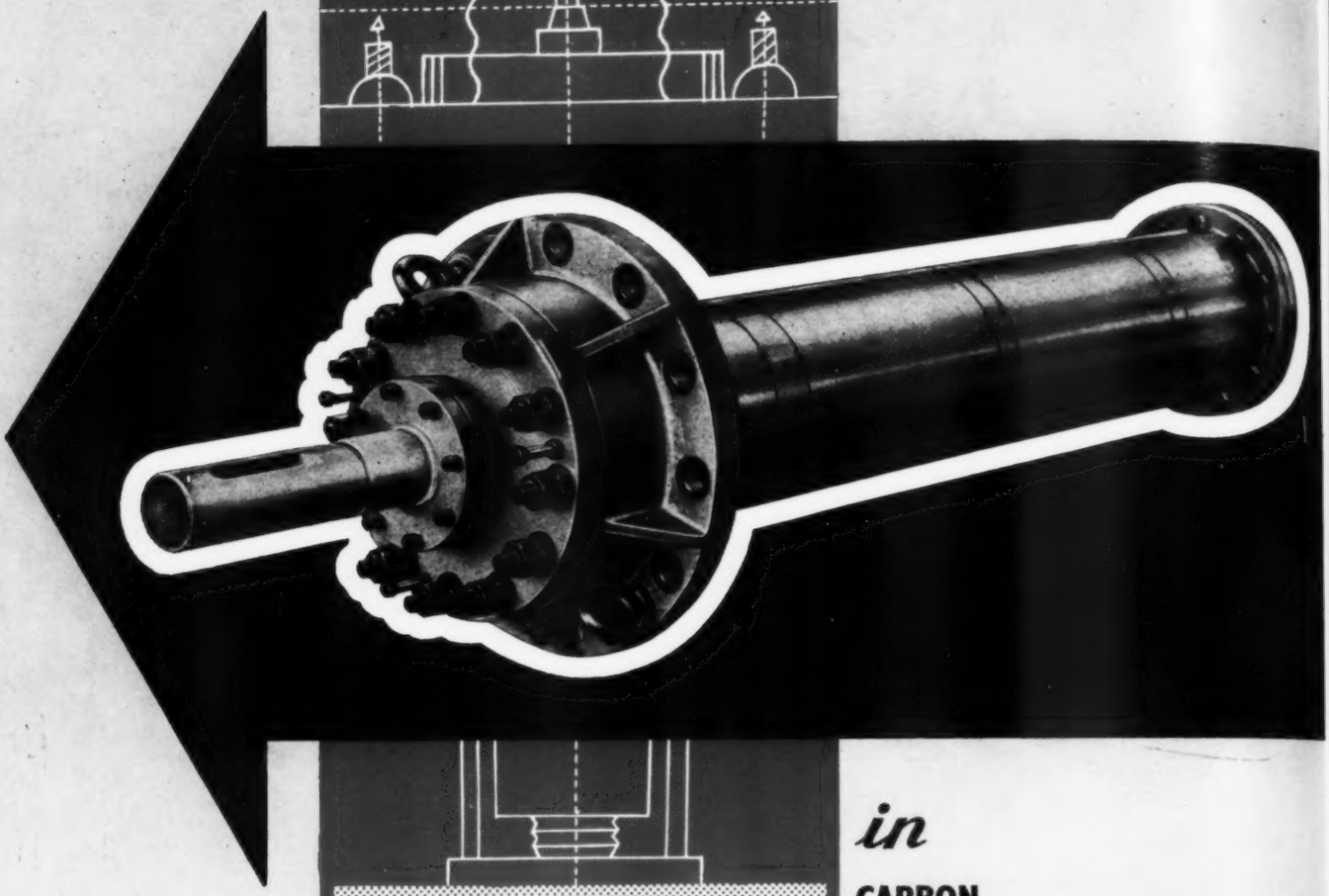

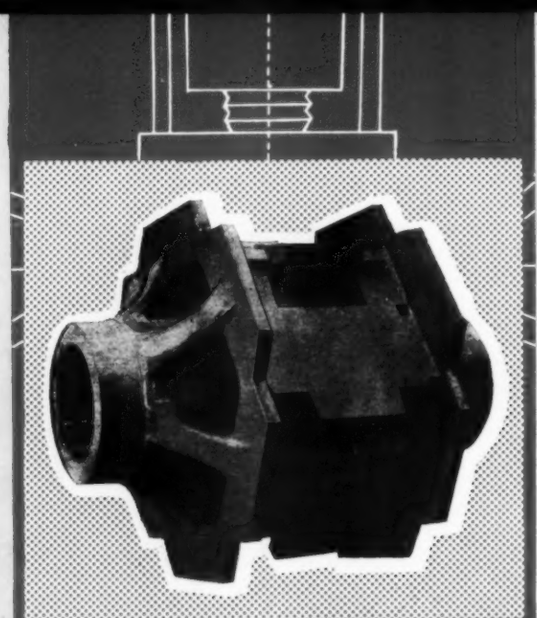

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THE ENGINEER

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No. 5488 **MARCH 31, 1961** VOL. 211

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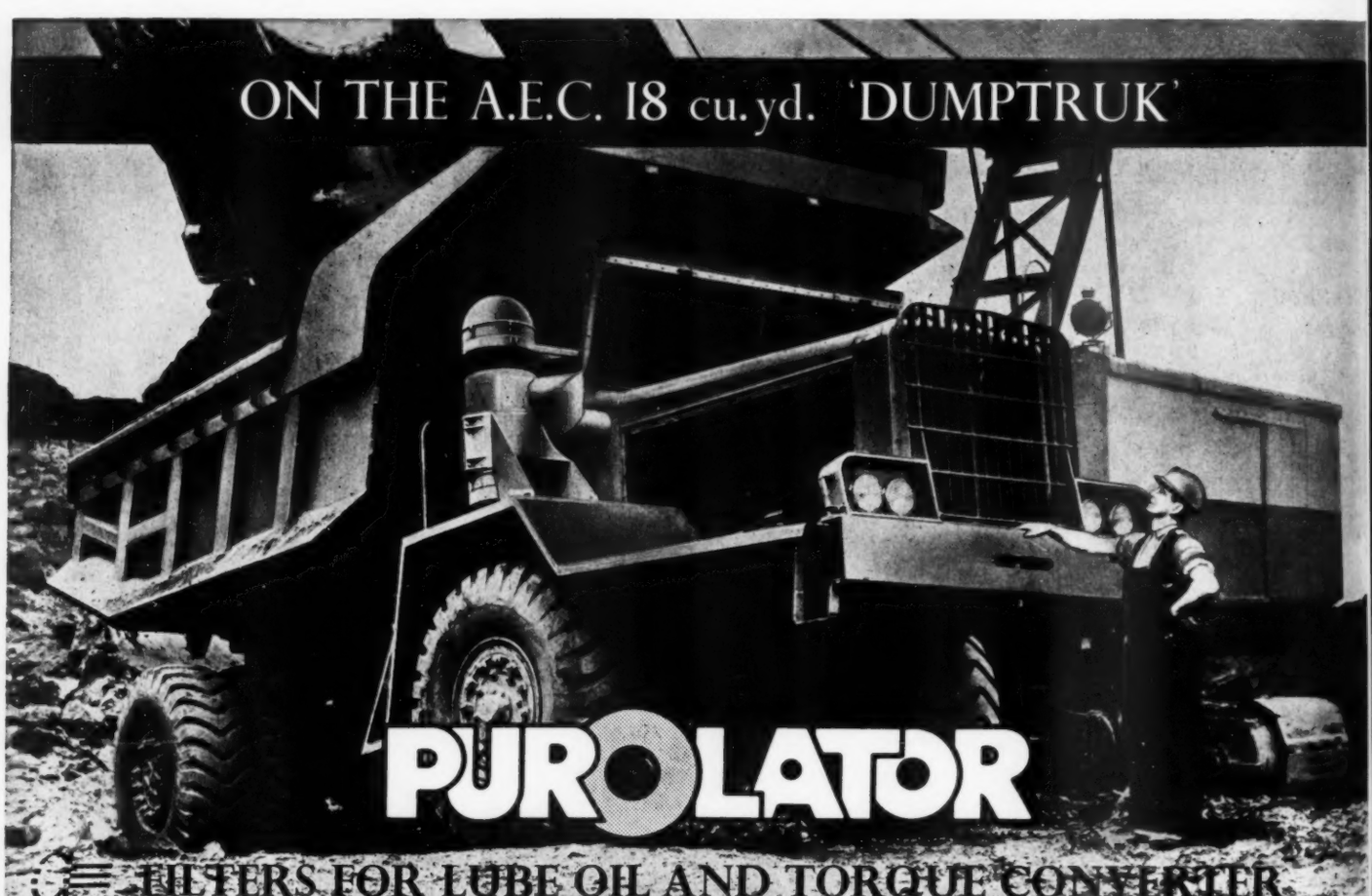

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THE ENGINEER

No. 5488 MARCH 31, 1961 Vol. 211

THE CHANNEL CROSSING

Publication of an English-language brochure entitled "A Comprehensive Cross-Channel Link" by the Union Routière de France, and the discussion last week at the Institution of Civil Engineers of the paper "The Work of the Channel Tunnel Study Group," have once again stirred up all the controversies surrounding the cross-Channel project in its various forms. The first fact which emerges is that even for such a bold scheme, controversy is not centred on questions of engineering practicability. For the tunnel scheme which the I.C.E. paper discusses, clearly there is much originality in the engineering proposals (for instance a rate of construction of 540 metres per month for the main tunnel is confidently predicted), and likewise the exploratory surveys are a fascinating achievement. Much first-class work has been carried out here. But nobody now questions that either a bridge or tunnel is perfectly practicable to build. The contention centres on almost the same controversy as has been so prominent in our correspondence columns over the last few weeks, namely road versus rail. The Union Routière de France has produced estimates of future traffic which differ from those of the Channel Tunnel Study Group, and it not only refutes the Group's conclusion (as reported in THE ENGINEER about a year ago) that the extra capital cost of the bridge would yield no extra return on the money invested, but it furthermore asserts that "it would be unreasonable . . . to construct . . . a structure (i.e. a rail tunnel) more appropriate to the ideas of the nineteenth century than of today." The traffic and economic survey which supports these general conclusions is, to say the least, elaborate. Other arguments — put forward at the I.C.E. discussion for instance — question not only the relative economics but the engineering solution of the "traffic" as distinct from the "construction" side of the scheme. The Group's idea is that cars will be driven onto a train, from one end, and parked, nose to tail, on the train, with brakes on and in gear. The occupants would stay in their cars; the train would then proceed through the tunnel at a fairly high speed. This notion has come in for some strong criticism. Thus the traffic capacity, economics and the "amenity" aspect of the Group's preferred design are not necessarily accepted without question. The "Group" has studied alternative tunnel and bridge schemes; the "Union" proposes a bridge; and another rival project for a bridge is being studied in this country. So the situation is complicated.

It should not be overlooked that yet another alternative exists. Two weeks ago we described in this journal a French engineer's proposal which, in its simplest form, may be described as two training walls built into the Channel and connected by a bridge. By influencing the tidal currents so that the west to east flow of water is substantially increased, the winter temperatures of the eastern part of the English Channel and the southern part of the North Sea would be increased, and hence the winter climate all around favourably changed. The project is in principle of the same order of cost as a bridge, but with possibilities of returns of a much greater order. The Channel dam project exists only in outline. This is to be expected when it is remembered that something like a quarter of a million pounds has been spent by the Channel Tunnel Study Group on — it is stressed — a "feasibility study" only of the tunnel. Should the tunnel be built, further more detailed surveys and explorations will be needed to cover what is normally called "site exploration." It would be interesting to know what could be learned if, say, a tenth of the sum needed to demonstrate the feasibility of the tunnel were devoted to research into and investigation of the Channel dam idea.

NORTH ATLANTIC SHIPPING BILL

The terms of the North Atlantic Shipping Bill, which enables the Minister of Transport to provide financial assistance to the Cunard White Star Ltd., for the purpose of constructing a passenger liner for the North Atlantic service, were published last week. They provide for advances up to a maximum of £18,000,000 and for making part of the advances as a grant if the rate of interest exceeds 4½ per cent, the amount of such a grant being limited to £3,250,000. The White Paper, also published, sets out points of agreement between the Government and the Cunard Steam-Ship Company, Ltd. These provide security for the repayment of all advances and ensure that the owning company will continue under British control.

The presentation of the Bill to Parliament and the news that a number of firms have been invited to tender for the contract is greatly to be welcomed, despite criticism in certain quarters. After all, the Chandos Committee which investigated the whole question of future trends in trans-Atlantic travel, including the effects of competition from the air, did make certain recommendations! It appears essential, for prestige or other reasons, for British ships to continue to participate in the trans-Atlantic trade and not be eliminated by heavily subsidised foreign lines. At present the Cunard Company's share of the North Atlantic passenger traffic is about 27 per cent so that not to replace the "Queens" would mean loss of earnings, reduction in taxes collected by the Government, loss of employment for British seamen and engineering craftsmen. The decision to build a replacement of the "Queen Mary" would be a welcome fillip in the present state of the shipbuilding and marine engineering industries and at least keep a number of men from swelling the ranks of the unemployed and so effect a saving of Government expenditure on another count. It may be emphasised that although a grant is mentioned, the main advance is not a subsidy but a loan repayable over twenty-five years. The amount of money

involved seems to be small when considered in relation to the amount of public money advanced to the aircraft and other industries; and certainly it will seem to engineers, if there is an either-or involved, that it would be more profitably employed in building a liner than in sponsoring a nuclear powered merchant ship known in advance to be uneconomic. The Government financial help, however, will be open to criticism if assistance is only offered to the Cunard Company for it is to be hoped that the present Bill signals the end of Government complacency and a realisation that many other shipowners require help. This help may need to be financial where taxation has precluded the setting aside of sufficient reserves to meet the high cost of new building or where a service may have to be abandoned due to foreign state competition and unfair practices completely nullifying efficiency and commercial know-how. A lot of lip service is paid to Great Britain being a maritime nation, but there appears to be little conception of the value of its shipping services and the fact that 99 per cent of all the country's trade is seaborne. Thus it is to be hoped the proposed aid to be applied to building a passenger liner for the North Atlantic Service will be extended to help British shipping to maintain its present strength or even regain some of the ground lost to subsidised competitors.

WHAT IS A PROFESSIONAL ENGINEER?

Last week the Engineers' Guild organised a conference on "The Professional Engineer — His Employment and Development." It was held at the Connaught Rooms in London and three papers were presented, "The Engineer and the Technician," by D. J. Mann, of Unilever, Ltd., "The Engineer in Management," by A. R. Cooper of the Central Electricity Generating Board, and "The Engineer in Society," by Lord Chandos. Though no one who was there will doubt the success of the occasion nothing very new was said; it was merely said very well. Interestingly, though education was seldom mentioned, there seemed to us to be overtones of that subject sounding throughout. Nearly 19 years ago Sir Arthur Fleming gave a detailed definition of artisans, technicians and professional engineers. We sometimes suspect that it might have been better if he had not! For, though several attempts have been made, no one has ever succeeded in propounding definitions of technologist and technician which are wholly satisfactory. One of the troubles is that though the technologist is supposed to be able to direct the work of the technician it sometimes happens that it is someone who by educational and other qualifications ought to be styled a technician that tells a technologist what to do. There is too a subjective matter of personality and insight to be taken into account. A technician with a wide range of interest and a forceful character may be better fitted than a narrowly educated technologist to understand the ramifications of a subject and be able therefore to direct the technologist to pursue studies of the subject in a particular way which he as a technician would be incapable himself of pursuing. Similarly a high quality technician may make a better designer than a technologist, since there are qualities needed for successful design which a technologist, under any definition we have so far seen, does not necessarily possess; a creative imagination, for example, and the horse-sense to prefer practical simplicity to the marginal advantages of a more complex design. Again, is the research man with high academic qualifications necessarily a better engineer than a creative designer, who may well lack the particular qualities of mind needed for success in research or in an academic career? So long as engineering remains an art as well as a science, and so long as university education retains its present form, it will remain impossible to claim that a graduate is necessarily a better engineer than a non-graduate. For little attention is given in a present-day academic course to the real problems of design and not much to the real problems of management. Nor at present does the works training go very far to put matters right. It fails to give a graduate enough handicraft skill to gain insight in that way into the properties of machines and materials, but, in a half-hearted and in our view mistaken attempt to do so, it fails to use alternative and better means of more directly teaching them something about management, machines, materials and men.

"If engineers behave like artificers," said Mr. Cooper, "they will be treated as artificers. If they want to be regarded as something potentially higher in the business hierarchy they will have to widen their spread of interests and make it obvious to the world that it is part of their creed for this widening to be encouraged." University courses too narrowly technological in content do little to help; the technician, supposedly inferior, probably has a better opportunity to widen his knowledge and experience than does the graduate. What some of the subjects for the study of engineers ought to be was suggested in the last of the three papers. Let us quote from it. "The engineer is the aristocrat of the twentieth century. In the material field . . . he has both the training and the knowledge to engage in speculations about the material future of mankind, and also the means of bringing these speculations to life. . . . Just as the great landowners . . . had the means of bringing waste land into use and of bringing skill and experience in agriculture to the rescue of the people, so today the engineer, through infinitely more complex processes and calculations, holds out to mankind in the material field a future in which the word starvation should become obsolete, in which the word underdeveloped would become an anachronism, and in which the word unemployment will cease to be used, and in which the word leisure would be substituted. . . . Men cannot live by bread alone, and if you think that by the production of cheap bread you will have done all that an aristocracy should, you will be sadly mistaken."

CARPET OF TECHNICAL ADVANCE

Some time ago, speaking in the House of Lords, Lord Caldecote, in the course of criticising the Government for causing delays in the rate of development of aircraft and guided weapons, referred to the "carpet of technical advance." Clearly he had the Arabian Nights concept of a carpet in mind, not something as static as those we tread under foot. For he spoke of it as moving forward at a speed which is not under our control but which is determined by technical progress in the world around us. Lord Caldecote's object was to castigate the Treasury and other ministries concerned with industry; and though he thought the Treasury was often blamed for delays when in truth the cause lay elsewhere, he had not "the slightest doubt that the system of control at present being used, in which the Treasury plays the leading rôle, is the cause of a great many needless and wasteful delays." He traced the trouble to the fact that decisions on highly

technical matters are taken by men with little technical knowledge and he felt that experienced senior technical men should be given greater authority.

Of course, Lord Caldecote's remarks have application to fields other than that of aircraft and missile manufacture. There is a "carpet of technical advance" in every field of engineering endeavour and for only very few of them do engineers from this country set the speed at which it flies. It is not easy to keep up; and needless delays in getting decisions made can have serious results. Sometimes, indeed, we wonder whether engineers in this country appreciate how quickly engineers in other countries are driving the carpet along. Fortunately there are a number of forward looking firms in this country who ensure by contractual or by purely friendly relationships with firms on the Continent that there shall be an exchange of knowledge and experience in design and production methods and even some co-operation in research. There are others eager to ensure, whenever an Institution takes its members abroad or any other opportunity offers, that senior and even junior members of the staff shall go abroad and see what is happening there. But unfortunately there are also some, primarily concerned, perhaps, to serve the home market, who have very little conception of what is going on abroad. Quite apart from the national interest and from the financial profits which can be earned we hold it valuable that a firm should enter the export markets in order to discover how fast the carpet of technical advance is flying along. For we fear that, long since, a number of the more complacent firms lost their places upon it.

HOLE WATCHING

There was a time when contractors digging the foundations for some new building in a city street surrounded the place with hoardings. No doubt they feared that if protection were not provided members of the public would either invade the works or fall into the hole. What went on behind the hoarding was thus done in complete secrecy from the public except, of course, when bus-top passengers were elevated sufficiently high above the ground to be able to get a passing glimpse. Then, just as a number of scientific discoveries have been made through accidental observation, some bright spark of a publicity johnny observed the obvious. He noticed that whenever a few men armed with concrete breakers or pickaxes opened up a hole in the road a crowd of idlers would lean over the temporary barriers around the hole intently watching the whole operation. Yet, a building contractor was likely to make the hole made in the road look utterly insignificant. The bright spark, therefore, though no doubt with some difficulty, swayed his management to make an experiment; so that in due course part of the hoarding disappeared and was replaced by a special gallery from which an extensive view could be obtained of earth-moving machinery and cranes in action, the placing of reinforced concrete foundations and the sprouting upwards of steel or reinforced concrete pillars from the bottom of a hole of really satisfying dimensions. No longer was the public to be reduced to peering through knot-holes and cracks in the hoarding in order to find out what was going on. The idea caught on; the galleries were well populated and, indeed, in time, they became quite palatial. Modern examples provide cover from the weather as well as a view of the works.

But in one way all such galleries are defective. So long as the attraction is a hole in the ground the galleries serve their purpose very well. But once the superstructure begins to grow it becomes less and less easy for the public to see anything at all from the galleries. One of the attempts to meet this sad situation has been the installation of closed television equipment so arranged as to look in on different parts of the building on a kind of rota. But apparently looking at reality and watching a television screen are to the hole-watching public very different things. For whereas, as long as the hole is still open and there is something to see the throng of watchers is day-long present, once there is nothing to see but a television screen only the odd idler looks in. One may doubt, indeed, whether he has any real interest in the progress of the work at all; more probably he has no TV set at home and is wondering whether to buy one. Television having proved far less than a signal success a new idea is now to be tried in the attempt to hold the interest of sightseers once the building has reached such a stage in its construction that the observation platform is of little further use. The New Zealand Government, in conjunction with Holland & Hannan and Cubitts (Great Britain) Ltd. is to provide a large window through which at times the public will be able to see inside the structure of New Zealand House now rising at the lower end of the Haymarket in London. But the main attraction is to be a brightly lit pictorial display showing scenes in New Zealand; and other building projects undertaken by Cubitts. As a final touch of seduction there is also to be soft background music! On visiting the gallery recently we found no one there and black darkness behind the window. The music was not sufficiently seductive. We did not tarry.

The Engineer—100 Years Ago (MARCH 29, 1861)

"PHOTO-LITHOGRAPHY"

"Photo-lithography is the invention of M. Poitevin, Colonel Sir Henry James, and others. A lithographic stone is covered with gelatine and bichromate of potash, and a photographic impression taken on it. The stone is then damped with water, which is absorbed by those parts not acted on by the light, and the greasy ink on being passed over it in the usual way adheres to the sunned portions forming the image. This process, modified by Colonel James, has been used with very great success in completing the ordnance survey, the cost of enlarging or reducing plans being reduced to a minimum. Many thousands have been saved to the country by this means."

British Transport Museum

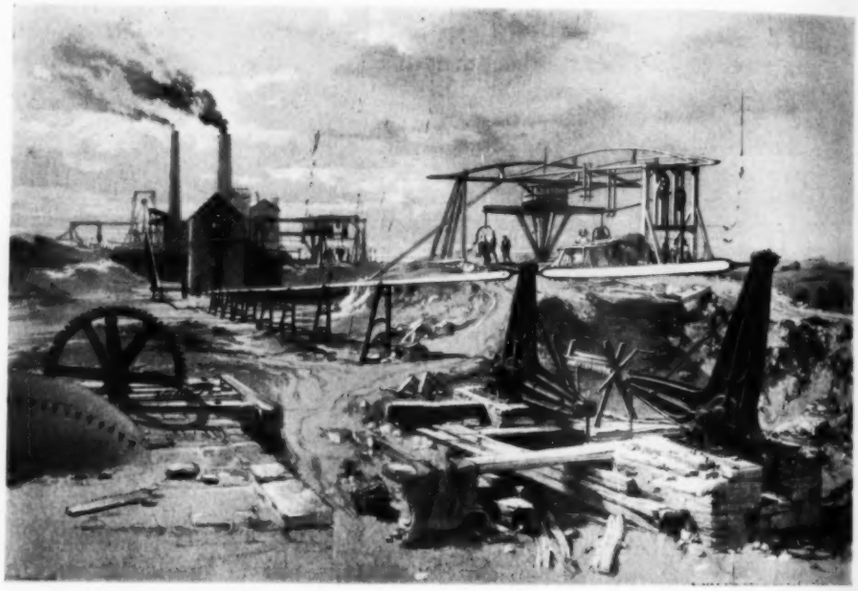
The recent opening of the first section of the British Transport Museum in London was an event keenly anticipated by transport enthusiasts, but the museum, though certainly of great interest to the transport specialist, is by no means for him alone. Only small items—models, prints, drawings, vehicle and boat fittings and the like—are displayed at present, but the section now open to the public is fully self-contained, and gives a foretaste of what is to come when the larger exhibits are put on show.

WHEN the British Transport Commission came into being on January 1, 1948, the property it took over included several collections of historical items which had been accumulated by the former independent rail, canal and road transport concerns. These collections were widely scattered, and, with the exception of the exhibits at the York Railway Museum, founded in 1922, none was normally accessible to the public. As a first step towards the systematic preservation of all material of historical interest relating to public transport, a Curator of Historical Relics was appointed in 1951. The initial task of the Curator, Mr. John H. Scholes, who had long experience of museum work, was to find out exactly what existed, and where everything was. It was a formidable undertaking ; no comprehensive catalogue existed, for the material had formerly been in many different ownerships. Its variety, too, is enormous, ranging as it does from buildings to locomotives and rolling stock, road vehicles to boats, scale models to uniforms, china and glassware to oil paintings ; in fact it includes everything of historical importance except documents, which are the responsibility of another department. The list is not complete, large as it is. It never can be as long as there is public transport, for some things which are not of obvious historical importance now will become so in time. Indeed, one of the problems facing a museum to-day is to decide what, in current use, it is historically important—and practicable—to preserve.

But the list of relics in the care of the Curator is impressive—from a display point of view it is daunting, and it is clearly impossible at present to display all the relics —even those which are reasonably portable —in any one place and at one time. No less than seventy-one railway locomotives are either preserved or scheduled for preservation when their working life is over, and there are long lists of rolling stock, horse-drawn and motor road vehicles, trams and trolley buses, stationary steam engines and some miscellaneous items such as machine tools, to say nothing of buildings and structures such as Telford's Pont-Cysylltau aqueduct of 1805 in North Wales. Buildings and other large structures obviously had to stay where they were if they were to be preserved at all, but most of the other items were portable in varying degrees, and it was envisaged from the beginning that a public display worthy of the material should be provided.

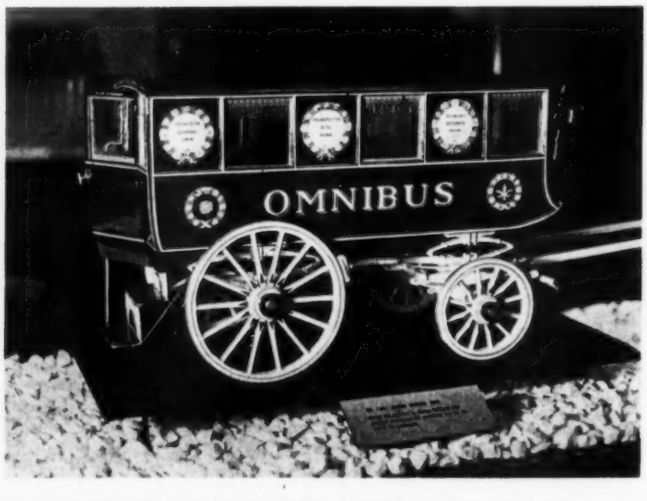
For the time being it was only possible to ensure that the various items listed were properly stored, and to take the necessary steps to ensure that they were not destroyed, as has happened all too often in the past. Many people deplore the fact, for example, that the old Great Western Railway broad gauge locomotives " North Star " and " Lord of the Isles," which had been preserved at Swindon for many years, were scrapped in 1905, leaving only one genuine broad gauge locomotive in existence—the old South Devon Railway engine " Tiny," which is far from typical.

But in due course it became possible to take more positive action as far as the public was concerned, and a start was made by holding a series of temporary exhibitions dealing with particular aspects of transport history ; these were quartered in the shareholders' room at Euston station, itself of historic interest. These temporary exhibitions were popular, and indicated the need for something larger and permanent.



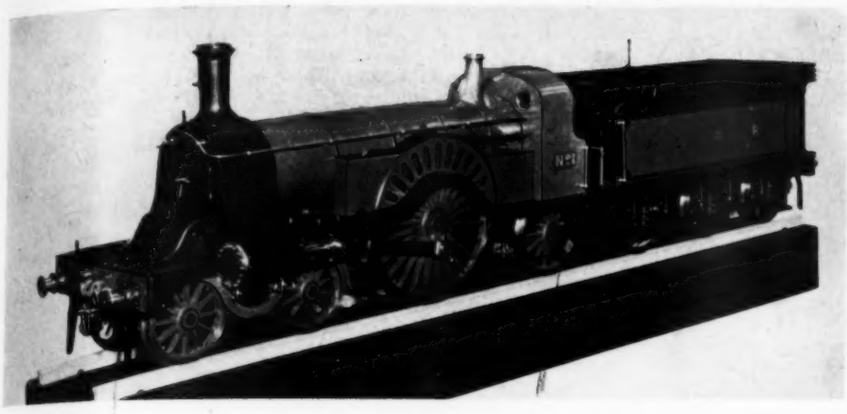
Railway construction work involved heavy engineering works, some of which inspired artists like J. C. Bourne, whose lithograph of the pumping gear for Kilsby tunnel (1839) is one of many prints at Clapham

In 1959 a former London Transport bus garage at Triangle Place, Clapham, London, S.W.4, became available, and the headquarters of the Curator of Historical Relics were transferred there. The garage, originally a tram depot, had been rebuilt after



George Shillibeer's horse-drawn omnibus of 1829 represents public transport in London in pre-railway days

Early railway coaches had much in common with road vehicles ; this model is of a vehicle of 1834 used on the Liverpool and Manchester railway



In the latter half of the nineteenth century several railway locomotives were built for fast passenger traffic. Of these Patrick Stirling's 8ft "singles" of 1873 were classics

war damage, and is now a large modern building with extensive offices, part of which has been adapted to house the first section of the public museum. The premises are accessible by public transport from all parts of London and, having good Underground Railway connections with all the main railway termini, can easily be reached from further afield. There is a total floor area of about 85,000 square feet, and of this about 55,000 square feet are occupied by the former garage, a single-storey, roof-lighted building. The remainder consists of repair bays and the two-storey office building. It is in the latter that the first section of the public museum, opened on March 29, is housed.

There are seven display galleries, the first of which serves to introduce the subject in a general way. Photographs, prints and small exhibits, including a scale model, made by

Road passenger vehicles developed more slowly, as this model of a London General Omnibus Company's "garden seat" bus of the 1880s shows

the apprentices at Crewe, of the first and only Great Western "Pacific" locomotive, "The Great Bear," of 1908, and a model of the Liverpool and Manchester Railway first class passenger coach "Experience" of 1834, give the visitor a broad idea of what is to follow. Gallery two is devoted to road passenger transport in the London area; three to Royal travel by rail; four to art as represented by paintings of railway and other transport subjects; five to scale models; six to prints; and seven to posters, notices and advertising material of various dates. In addition to the galleries within the building there is a roadway at the back where actual vehicles will be displayed from time to time. For the present these will be road vehicles, which can easily be brought out of the adjacent store. Up to about ten vehicles can be displayed on this roadway, but what is actually shown must depend on circumstances. This includes the weather, for the Clapham stock of vehicles includes many which have been beautifully restored to their original liveries and condition.

Such is a very brief description of what is at present on show at Clapham. A more detailed list could be provided, but it would be nothing more than a catalogue, and catalogues, though valuable for reference purposes, do not make very interesting reading. Moreover, since the small exhibits collection is much larger than the exhibition space can accommodate, items will be changed from time to time, and a detailed catalogue of exhibits could soon be out of date.

Transport enthusiasts, including specialists in one or more branches of the subject, need no recommendation to the Museum; they have been waiting for it. But what of other people? Is there anything of interest for them? Public transport has had such a profound influence on the history of the world that there is no one whose life has not been affected by it. Those who have no sectional interest may choose to reflect upon this fact of far-reaching effect; the Museum offers them plenty of material. There is, in fact, no end to the thoughts and ideas that can be stimulated and the questions raised by the exhibits. It is of interest to note, for example, in the print gallery, the gradual acceptance by contemporary artists of the new idea of railways. Some of the earlier prints show that the artist, though competent to draw those things with which he and his contemporaries were familiar, found it difficult to produce a true picture of a locomotive or train. Yet it was a difficulty which soon passed, as the works of J. C. Bourne, for example, show. His drawings, dated 1839, are superb in their delineation of technical detail. There is scope for reflection in some of the early technical drawings, too; they are more than just examples of skilled draughtsmanship; they are pleasing to the eye as perhaps even a technical drawing should be but often is not.

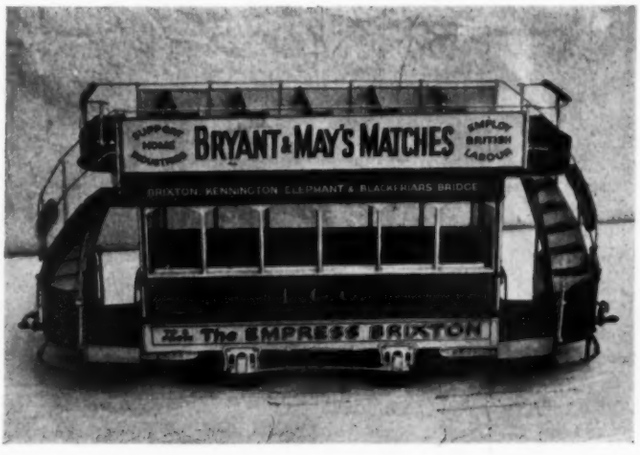
From a purely artistic point of view there is much to be seen. Oil paintings of great railway engineers, and of railway and canal scenes; the traditional "roses and castles" paintings on canal boat cabin doors and utensils; silver and glassware from railway

Overlapping with the tramcars in service, and a forerunner of profound changes, was the petrol bus. This model is of the L.G.O.C. "B" type vehicle of *c.* 1910

hotels and some items from several different Royal trains provide a wide cross-section of art both in the service of, and as inspired by, public transport. Colourful, too, are the many railway coats of arms displayed in more than one gallery.

If it is mechanical engineering which interests the visitor, he will find much to occupy his time, though for the present he will have to be content, in the main, with models. Of these there is an abundance, including a fine set of scale model locomotives and rolling stock of various companies and periods. Of craftsmanship there are endless examples, ranging from the models mentioned to such things as oil lamps, badges, buttons, crests and countless railway, road vehicle and boat fittings.

Some of the larger exhibits owned by the Museum, which cannot be shown at present,



At the end of the nineteenth century the electric tramcar was common all over the country. Models of these vehicles, too, are at Clapham

are featured in a series of film strips, for which four projectors are installed on the upper floor. The visitor can see in these film strips a short history of Royal travel, of locomotive development up to 1948, and of carriage design. Other film strips will be shown at intervals.

There are endless questions answered, and a few posed. What was a canal boat legging board? What did a London General Omnibus Company "knifeboard" horse bus look like—or a "garden seat" bus—or a "B" type petrol bus? Was the horse tram anything like the electric vehicle, and did either pass on any of its features to the trolley bus? What was railway advertising like in the nineteenth century? To-day, all public railways in Britain run on the left-hand track—did they always? All these questions are answered by the exhibits in the Museum. Some are not answered fully; there is, for example the question of whether or not railways ever carried "outside" passengers, that is, on the roofs of vehicles, like coaches or early trams and buses? Prints in the Museum show passengers being carried in this way, but it is not clear whether or not this was a local or a general practice, or how long it lasted. Truly there is ample food for thought at Clapham.

In his journey through the galleries the visitor is helped by modern methods of display. There are various means of displaying exhibits in a museum, and one of the commonest faults to be found in the past was that of trying to get too much in the space available. At Clapham, those responsible have wisely refused to overcrowd the galleries, though the temptation must have been great, in view of the large amount of material available. It would be annoying to the visitor to say the least, to find that the very detail of a particular exhibit he wants to see is either hidden by something else, inaccessible because of walls or showcase ends or is indistinguishable in the general gloom of bad lighting. On the contrary, at Clapham, though a remarkably large collection is displayed it is refreshingly accessible for viewing, and the skilful use of lighting where necessary makes it easy to do what, after all, the visitor expects to do—see what he is looking at.

The Museum is open from 10.0 a.m. to 5.30 p.m. every day except Sundays and a limited number of public holidays such as Christmas Day. There is an admission charge of 1s. per person, with reduced rates for parties.

CANTAT Transatlantic Cable

H.M.T.S. "Monarch" is due to sail from Greenwich on April 4 to begin laying the CANTAT telecommunications cable between the United Kingdom and Canada. This will be the first link in the Commonwealth round-the-world cable, and the first commercial installation of the British lightweight unarmoured submarine cable for deep-sea routes.

THE present Transatlantic telephone cable system consists of the TAT-1 and TAT-2 routes, from Oban and Penmarch (France) respectively, to Clarenville in Newfoundland. Each consists of two cables with single-way repeaters, but on the section from Clarenville to Sydney Mines (Nova Scotia) the traffic from the four deep-sea cables is carried by two cables with two-way repeaters.

All cables on the above routes are armoured, and those on the main sea crossings are of American design, but the British Post Office was responsible for providing the two links between Clarenville and Sydney Mines. Meanwhile development had taken place of a British deep-sea cable design proposed by the Post Office in 1951. This is an unarmoured coaxial pattern with polythene insulation and sheath, having as its strength member a central high-tensile torsionally-balanced steel strand around which the inner copper conductor is formed. The cable was described in our February 3 issue, page 178.

The first commercial application of this lightweight cable will be on the deep-sea section of the CANTAT cable between Oban, Scotland, and Hampden, Newfoundland (2100 nautical miles), the laying of which from the cable ship "Monarch" begins next month, the ship being due to sail from Greenwich on April 4. This will be the first stage in the round-the-world cable system recommended by the Commonwealth Telecommunications Conference in 1958.

"Monarch" is now taking cable on board at Greenwich from the Telcon Works of Submarine Cables, Ltd., by whom the 1600 nautical miles of armourless deep-sea cable and 552 nautical miles of shallow-water cable required for the main sea crossing of CANTAT have been manufactured. Production of the first length began at the Greenwich factory in November, 1959.

A screened submarine cable is being supplied by Standard Telephones and Cables, Ltd., for extending the link overland across Newfoundland from Hampden to Corner Brook (about 70 nautical miles) and a further 400 nautical miles of submarine cable is being made by Submarine Cables, Ltd., for the sea crossing from Corner Brook to the Canadian mainland at Grosses Roches.

An inspection of the cable ship "Monarch" took place during the loading operation. Cable is loaded into the four tanks in 25-mile sections and the repeaters are spliced in on board. There will be three legs in the operation, the first being of 725 miles and beginning with the picking up of the shore end of the cable at Oban, which has already been laid. Speed of laying is 6-7 knots. When repeaters have to be laid between the 25-mile sections, speed is reduced and does not exceed 1½ knots. In this operation a method devised by the Post Office, and already tested on the TAT-2 system, is to be used. The repeater by-passes the laying gear by means of a steel rope which passes through the gear and is attached to the cable on each side of the repeater. During normal cable laying the cable is laid out over a stern sheave by a series of five pulleys in line. The first pulley and its gear accept the cable from the tank and automatically disengage the cable from the laying gear at a repeater by the action of a diverter ball. The by-pass rope passes round the pulleys and the repeater moves alongside the gear in a trough which begins near the cable tanks and finishes at the stern sheave. Part of the trough can be seen in Fig. 1. A parachute is attached to the repeater to retard its descent. In order to prevent laying tension coming on the cable before the stocking following the repeater is clear of the gear, an hydraulic plunger puts a tuck in the by-pass rope for about fifteen seconds near the completion of the operation.

The radar, navigational and communications equipment of the Post Office cable ship "Monarch" has been extended from time to time since the ship was built in 1946. Radar equipment now comprises a Decca TM909 true motion radar as well as an older Type 12 radar by the same manufacturer. A Decca navigator and Decca track plotter are installed as navigational aids over a range of some 240 miles from this country, while a Dectra equipment and two Loran sets provide long-range services covering the whole of the Atlantic crossing. The radio room is equipped on an unusually comprehensive scale, for in addition to the facilities required by Ministry of Transport regulations a high-power single-sideband r/t transmitter was installed two years ago and has now been supplemented by a 1kW version of the same

Fig. 1—Cable laying gear for lightweight cable and rigid repeaters on board H.M.T.S. "Monarch"

Fig. 2—Extrusion plant for polythene core of the lightweight submarine cable

equipment. The sets work into a Marconi Type 203 broadband linear amplifier, requiring no tuning when frequency is changed. A Muirhead " Mufax " facsimile equipment is carried for reception of weather chart transmissions. This service is now available from some seventeen stations in different parts of the world. During the CANTAT laying operations the charts will be received from Dunstable or Washington according to the position of the ship.

Continuous checks of the cable are carried on during laying by the transmission of crystal-controlled tones in different parts of the frequency spectrum to be used. According to the responses observed on oscilloscopes, minor adjustments are made by cutting the cable to different lengths between repeaters. The d.c. power supplies for the repeaters are obtained on board the ship from two rectifier cubicles fed by rotary converters running on the ship's 220V d.c. auxiliary system.

There will be ninety repeaters and seven submerged equalisers in the main crossing. Housings for the repeaters have been manufactured by Submarine Cables, Ltd., and the repeaters themselves by Standard Telephones and Cables, Ltd. The electrical unit occupies the centre of the housing and is hermetically sealed in a brass cylinder. Gain is obtained from two amplifying paths in parallel, each containing three valves, and having a common negative feedback network. Electrically, the CANTAT repeaters differ from those used in the shallow water section of TAT 1 and TAT 2 in four major improvements :

(*a*) A new long-life valve is employed which enables the voltage across each repeater to be greatly reduced. An improvement in heater-to-cathode insulation makes it possible to derive this voltage across the heaters of the six valves in series.

(*b*) A new monitoring network is incorporated for locating all usual types of fault, including, for the first time in a British repeater, the source of a wideband noise fault.

(*c*) The insulation of the electrical unit to earth has been improved so that the repeater can now operate continuously at 5kV to earth.

(*d*) Means have been included to prevent a high-voltage surge at the repeater terminals from damaging any of the repeater components. Such a surge could be generated by a sudden earth fault on the cable due to damage by a fishing vessel's trawl gear.

In addition to the manufacture of repeater housings, Submarine Cables, Ltd. is supplying complete repeaters as well as cable for the Newfoundland-Canada section, from Cornerbrook to Grosses Roches. Equalisers are being supplied complete by Standard Telephones and Cables, Ltd. These are required because it would be uneconomical to carry out all equalisation for interaction and mismatch losses in the repeaters themselves. Deviations in each band would have to be maintained to +0·03dB per repeater section and the number of components required in each repeater to ensure this accuracy would adversely affect the reliability of the repeater. Orders for the repeaters, equalisers and cable were placed with the contractors in 1959 by Cable and Wireless, Ltd., which is jointly responsible with the Canadian Overseas Telecommunication Corporation, of Montreal, for financing, laying and maintaining the Transatlantic section of the cable.

Between Scotland and Newfoundland the CANTAT cable will provide sixty circuits. The frequency bands for transmission will be 60 kc/s to 300 kc/s in the direction Corner Brook to Oban and 360 kc/s to 608 kc/s in the reverse direction. The latter band includes 8 kc/s for the use of the continuous tone monitor. The terminal equipments at the shore stations translate the five groups of twelve circuits into the appropriate bands and inject section, system and cable pilots for maintenance purposes. Each group of twelve circuits carries a 60 kc/s section pilot to control the performance of the group section path within close limits and to indicate equipment failures. The system pilots are injected at the edges of the line-frequency band to indicate changes due to cable ageing and temperature effects. The cable pilots record the absolute changes with time in the cable system. Changes in cable temperature are corrected by switching suitable networks into circuit. Telephone and telegraph circuits are provided for engineering use during maintenance of the system.

During a visit to the Greenwich factory of Submarine Cables, Ltd. after an inspection of H.M.T.S. " Monarch," visitors were shown the process of forming the inner copper conductor of the cable round the central steel strand by a box-seaming method. Polythene insulation is extruded round the inner conductor in the plant shown in Fig. 2. Diameters are checked electronically and the signals used to control the speeds of the haulage motors. After application of the outer aluminium tape conductor to the core so formed, a further polythene extrusion over this conductor and the screening and protective layers completes the cable construction.

Polyether Foam Plant at Hirwaun

IN recent years special purpose synthetic rubber latex has been used to supplement natural latex and now there are in addition two new synthetic foams which are known under the general name of Polyurethane foam. These foams, Polyester and Polyether, differ as to raw materials but are made by a similar process to produce a rubber-like polymer. A comparison between the damping qualities shows that movement in Polyester foam is damped out almost immediately, which makes the material suitable for vibration insulation, while the Polyether foam unit takes longer to damp out movement resulting from the sudden release of a load, and so is more suitable for upholstery purposes. Indeed, the Polyether foam produced as a result of Dunlop research closely approximates the properties of latex foam and is now being produced at the Dunlopillo factory at Hirwaun of the Dunlop Rubber Company, Ltd.

The plant at Hirwaun is built to produce Polyether foam by either the " Pre-Polymer " or the " One-Shot " processes in which two kinds of small molecules are joined into a chain formation. In the former process the molecules are arranged in long regular chains, of moderate molecular weight, before polymerisation makes the structure permanent. In the second process the molecules join together in permanent form at the mixing stage to form less regular shorter chains of lower molecular weight. The accompanying diagram indicates the essential differences between the two foams as compared with latex foam of equivalent standard hardness. It is clear that the Dunlopillo Polyether foam made by the " Pre-Polymer " process will feel harder than Dunlopillo latex foam when first compressed, whereas Polyether foam of general quality, produced by the " One-Shot " process will feel much harder at first, but will give a falling-through feeling as the load is applied.

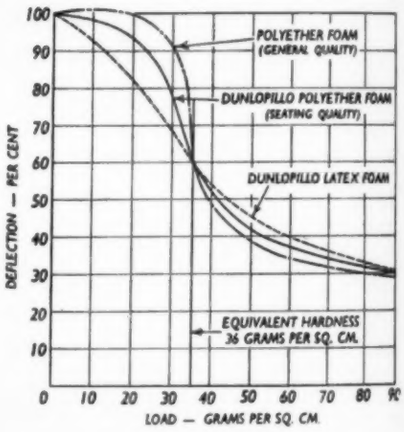
The machine producing the foam requires close technical control since it combines polymer preparation with product manufacture,

one machine carrying out the whole sequence of operations. Furthermore, it is essential that the special metering pumps feeding the mixing head should operate very accurately since the foaming is critical, so that a variation of 1 per cent in the output of a pump will result in the product being scrapped. Foaming commences and expansion takes place very rapidly. The plant is capable of producing 140 lb of finished foam per minute, which compares with 10 lb to 15 lb per minute from a latex foam plant of comparable size.

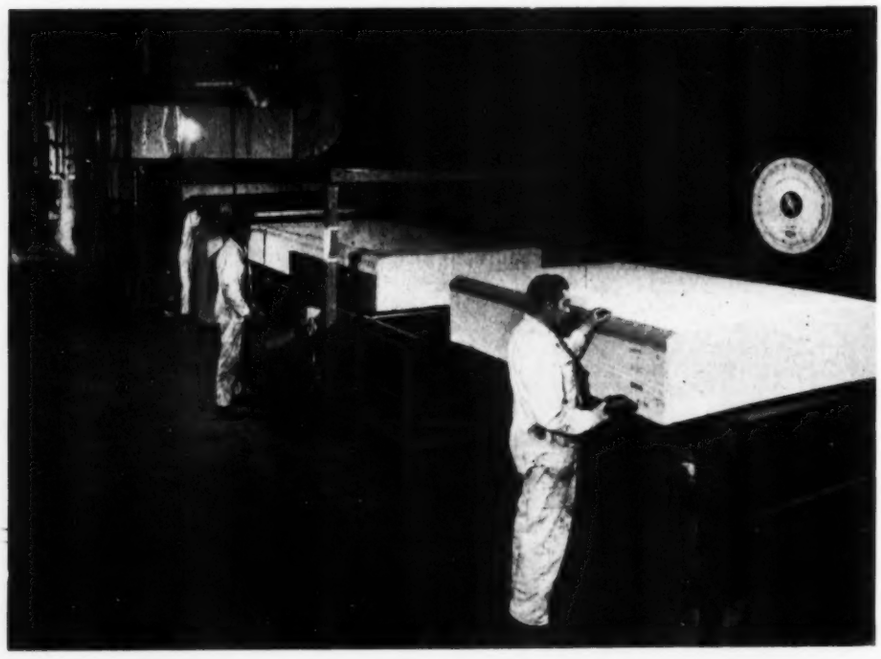
This product has certain economic advantages since the raw materials are stable in price which allows for long term marketing arrangements. Another point is that practically no heat is required for the process since it is exothermic. The main materials are isocyanate, which is derived from coal, and polyglycol, which is based on oil.

Road tankers deliver the raw materials to the Hirwaun plant and the isocyanate, which has a strong affinity for water, is discharged into two 5000-gallon tanks by means of dry air under pressure. Since the bulk storage tanks must not be opened the contents are measured by electronic probes. There are three 5000-gallon tanks into which the polyglycol is pumped. This storage space, which is kept at a temperature of about 70 deg. Fah. also contains three 1000-gallon mixing tanks in which isocyanate, delivered by dry air under pressure through a batch meter, is reacted with polyglycol. The reacted material is forwarded to two 500-gallon tanks and then is filtered and pumped through special metering pumps to the mixing head where catalysts are added to assist in the foaming action. Our illustration shows the automatic dispensing unit supplying the mixing head. Meanwhile waxed paper has been laid in a slat conveyor to form a trough and as this passes under the mixing head the liquid is continuously deposited on to the paper by a traversing nozzle. Foaming commences immediately and within about 10ft of travel there has been approximately a 30 to 1 increase in bulk to form a loaf some 20in high by 80in wide at a rate of 7ft per minute. With the loaf formed the paper is removed and the loaf passes under a horizontal band knife, to part the top skin, before passing through a drying and deodorizer oven through which air heated by steam battery heaters is circulated. An average temperature of 250 deg. Fah. is maintained to drive off the volatiles, and the fumes are exhausted by fans. On leaving the oven the top skin is peeled off and the loaf is passed through a mangle to ensure that any closed cells are ruptured. Twin oscillating saws automatically cut the loaf to length and it is then weighed. The mangling cutting and weighing operations can be seen in our illustration.

Automatic dispensing unit for supplying the mixing head



Load compression diagram



Loaf emerging from oven to pass through mangle and to be cut to length and weighed

For the process to be operated on an economic basis it is necessary that a market should be found for the skin and also for the off-cuts. The latter is used within the Dunlopillo Division: the material is forwarded to rotary cutters which reduce it to dice size and then it is blown up into a hopper from which it is fed by gravity to a spiral stirrer where reactive chemicals are added. The treated off-cuts are fed into a box former and compressed to produce "Repol" which is cut into 2in thick sheets and used as base blocks for mattresses.

A careful check is maintained in the laboratories upon the material: equipment measures and the load-compression properties the dynamic recovery of the foam, while there is a service test in which cushions are pounded a million times at the rate of four blows per second.

THE ENGINEER

Technical Contributors Section

MARCH, 1961

Geometry and Design of Crossed Helical Gears

By PROFESSOR W. A. TUPLIN, D.Sc., M.I.Mech.E.

Crossed helical gears, formerly called "spiral gears," are more useful than is commonly supposed. With teeth of involute form, their basic geometry is simple enough and indeed rational design procedure is simpler than the old-fashioned concept of "spiral gears" admitted.

THE line of contact between a tooth of an involute helicoid gear and that of a conjugate rack is the straight line of intersection of the plane flank of the rack tooth with the plane that lies normal to it and touches the base cylinder of the mating gear. In Fig. 1, which is an oblique view of a rack tooth, the points *A*, *B*, *C*, *D* and *E* are in the tip-plane of the rack, while *A*, *B*, *L*, *K* and *J*

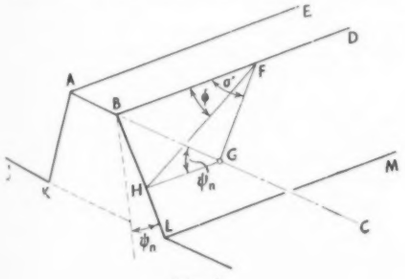


Fig. 1

define a normal section of a tooth of the rack, the flank angle being ψ_n.

The axis of the mating gear is parallel to the tip plane and is inclined to the direction of *BD* at angle σ. Any plane parallel to the axis of the gear intersects the plane *A B C D E*, is a straight line inclined at σ to *BD*. The particular plane that touches the base cylinder of the gear lies normal to the flank *M L B D*, intersects it in *HF* and intersects the tip-plane in *FG*.

Because the plane *ABLKJ* is perpendicular to the flank *MLBD*, and plane *FGH* is perpendicular to *MLBD*, therefore *HG* is perpendicular to *BL*. Hence $BH = BG \sin \psi_n$.

Since *HB* and *GB* are each perpendicular to *BD*, tan $HFB = BH/BF = BG \sin \psi_n / BG \cot \sigma$ or

$$\tan \phi = \tan \sigma \sin \psi_n \quad . \quad . \quad . \quad . \quad . \quad (1)$$

This gives the angle between the tip line of a rack tooth-flank and its line of contact with a mating tooth of a gear with axis inclined at angle σ to the direction of the rack tooth.

If the rack be now replaced by a "phantom rack" of the same nominal dimensions, that rack may simultaneously mesh with another involute helicoid gear (of the same normal base pitch) with axis not parallel to the axis of the first gear.

If the angles between the direction of the rack teeth and those of the gear axes are σ_1 and σ_2 the lines of contact of the two gear teeth that touch any particular rack tooth-flank are inclined to the tip-line of the rack tooth at angles ϕ_1 and ϕ_2 given by

$$\left.\begin{aligned} \tan \phi_1 &= \tan \sigma_1 \sin \psi_n \\ \tan \phi_2 &= \tan \sigma_2 \sin \psi_n \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (2)$$

In general, ϕ_1 and ϕ_2 are different and the only point of contact between the gear teeth is that of intersection of their two lines of contact with their common tooth-flank of the phantom rack.

If the gear axes are parallel, the lines of contact of gear teeth with a common tooth-flank of the phantom rack are parallel and by relative rotation the gears may be made to coincide. There is then line contact between a pair of mating teeth and, compared with this, the point-contact of crossed helical gears might seem to suggest infinitely small load capacity. In practice the ratio is finite, first because inevitable roughness of the tooth-flanks prevents parallelism of the axes from producing a geometrical line of contact and secondly because elasticity of the materials prevents non-parallelism of the axes from limiting contact to a geometrical point.

The first condition for meshing of involute helicoid gears is identity of normal base pitch p_{no}; this is readily achieved by using the same cutter to generate mating gears. The helical characteristic of any such gear is defined by its axial pitch p_a. It has been common to design gears so that the phantom rack with which they may be imagined to be meshing when at work has the same dimensions as the standard rack with which the tooth-generating cutter is conjugate, but that is an unnecessary restriction that makes design more laborious than it need be. Analysis of meshing conditions demands, as a first step, identification of the common phantom rack and location of the paths of contact for its two sets of tooth-flanks.

Given

Normal base pitch of gear teeth p_{no};
Axial pitches p_{a1}, p_{a2};
Numbers of teeth t_1, t_2;
Axis angle Σ;
Centre distance C.

Procedure.—Let the angles between the axes of the gears and the direction of the teeth of the phantom rack be σ_{m1} and σ_{m2}. Then $\sigma_{m1} + \sigma_{m2} = \Sigma$

Let the normal pitch of the phantom rack be p_{nm} and its normal flank-angle ψ_n.

At the meshing cylinder of each gear with the phantom rack, the normal pitch of the gear teeth is the same as that of the rack teeth and at the meshing line the common tangent to a gear-tooth flank and the meshing cylinder lies in the plane of the rack-tooth flank. Hence the helix angle of the gear at the meshing cylinder is σ_{m1} for gear No. 1 and σ_{m2} for gear No. 2.

The ratio of normal pitch to axial pitch at any cylinder is the sine of the helix angle there.

Hence

$$p_{nm}/p_{a1} = \sin \sigma_{m1}$$

and

$$p_{nm}/p_{a2} = \sin \sigma_{m2} = \sin (\Sigma - \sigma_{m1})$$

so

$$\sin (\Sigma - \sigma_{m1})/\sin \sigma_{m1} = p_{a1}/p_{a2}$$

whence

$$\left.\begin{aligned} &\tan \sigma_{m1} = (\sin \Sigma)/(\cos \Sigma + p_{a1}/p_{a2}) \\ \text{similarly} \\ &\tan \sigma_{m2} = (\sin \Sigma)/(\cos \Sigma + p_{a2}/p_{a1}) \end{aligned}\right\} \quad (3)$$

From the first of these

$$\begin{aligned} p_{nm} &= p_{a1} \sin \sigma_{m1} \\ &= p_{a1}/\sqrt{[1 + (\cos \Sigma + p_{a1}/p_{a2})^2/\sin^2 \Sigma]} \\ &= (\sin \Sigma)/\sqrt{[1/p_{a1}^2 + (2 \cos \Sigma)/p_{a1}\, p_{a2} + 1/p_{a2}^2]} \end{aligned}$$

. . . . . (4)

Technical Contributors Section (*continued*)

Thus the normal pitch of the common phantom rack with which the gears may be imagined to mesh depends only on the axis-angle and the axial pitches of the gears.

As the normal base pitch of the phantom rack is that of the gears

$$\cos \delta = p_{no}/p_{nm} \quad . \quad . \quad . \quad (5)$$

Now let the standard basic rack with which the gear-generating cutter is conjugate have normal pitch p_{ng}. Then in order that the phantom rack be identical with the basic rack, the relation between p_{a1} and p_{a2} is that given by (4) with p_{nm} replaced by p_{ng}. This is found to be equivalent to the condition that

$$\sigma_{g1} + \sigma_{g2} = \pm \Sigma$$

where σ_{g1} and σ_{g2} are the helix angles of generation by a rack-shaped cutter. They are determined by :

$$\sin \sigma_{g1} = p_{ng}/p_{a1} \qquad \sin \sigma_{g2} = p_{ng}/p_{a2}.$$

The meaning of the alternative signs is that, so far as meshing is concerned, the helices of generation may be of either right or left hand. (Reversal of hand does, however, reverse the directions of relative rotation of the gears).

Within this limitation there is wide latitude in design of gears for any given combination of axis-angle, centre distance and velocity ratio.

Meshing of Crossed Helical Gears

Any section of the phantom rack by a plane perpendicular to the axis of gear No. 1 is in the form of straight-flanked teeth of pitch $p_{nm} \sec \sigma_{m1}$. This must be the pitch of the teeth on the meshing cylinder of the gear with the rack. Hence if the radius of the meshing cylinder is r_{m1}.

$$\left.\begin{aligned} r_{m1} &= (t_1 p_{nm} \sec \sigma_{m1})/2\pi \\ \text{and similarly} \\ r_{m2} &= (t_2 p_{nm} \sec \sigma_{m2})/2\pi \end{aligned}\right\} \quad . \quad . \quad . \quad (6)$$

Let

$$C - (r_{m1} + r_{m2}) = e \quad . \quad . \quad . \quad . \quad (7)$$

The meshing line of each gear with the phantom rack is the line of contact of the meshing cylinder with a plane parallel to the axes of both gears. In Fig. 2, the meshing lines are A_1B_1 and A_2B_2.

Contact between either set of rack-tooth flanks and teeth of either gear is limited to straight lines in the plane that is perpendicular to the rack-tooth flanks and contains the meshing line. These planes are different for the two gears since the axes are not parallel. Contact between the gears is limited to points on the straight line that is common to the contact planes with the phantom rack. This line (the path of contact) is perpendicular to the rack-tooth flanks and intersects both meshing lines.

In the elevation in Fig. 2, the path of contact is therefore inclined at 90 deg $-\delta_n$ to O_1O_2 ; in the plan it is perpendicular to the direction of the rack teeth. It is shown in Fig. 2 as P_1P_2.

The projection of P_1P_2 onto a plane parallel to the axes is

$$\begin{aligned} P_1P_2 \cos \delta_n &= P_2H + HM \\ &= O_2H \,(\tan \sigma_{m2} + \tan \sigma_{m1}) \end{aligned}$$

Hence

$$q = O_2H = (e \cot \delta_n)/(\tan \sigma_{m1} + \tan \sigma_{m2}) \quad . \quad . \quad . \quad . \quad . \quad (8)$$

This gives the distance between the common perpendicular to the axes and the path of contact for one set of tooth-flanks. The path of contact for the other set of flanks is equidistant from the common perpendicular on the opposite side of it.

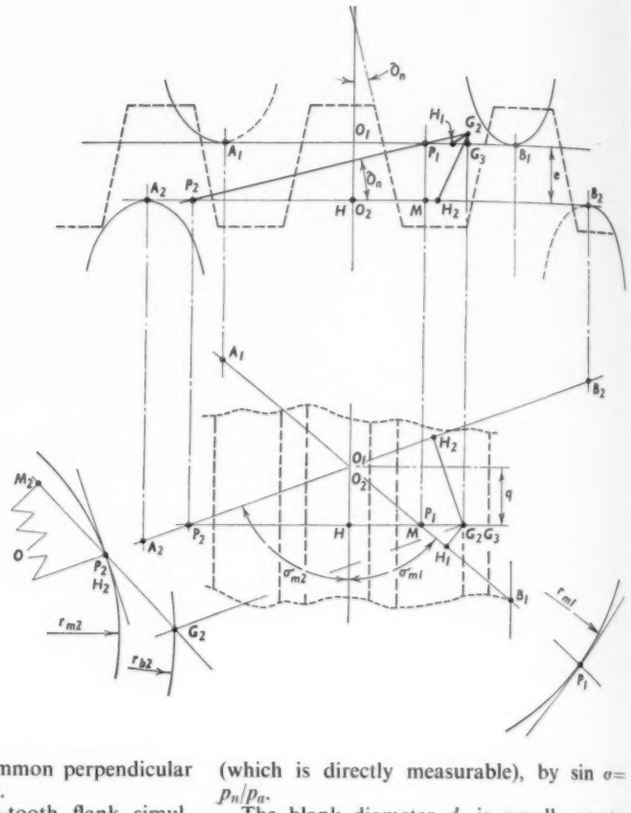


Fig. 2

In general each rack-tooth flank simultaneously touches a tooth of each of the mating gears in non-parallel straight lines.

By setting the gears sufficiently closely in mesh the condition of no backlash may be achieved. If the phantom rack is identical with the basic rack, this condition of no backlash corresponds to the full-depth engagement of gears generated by full-depth penetration of a cutter of the basic rack form irrespective of the exact values of the blank diameters.

(Note : This is not necessarily true if $\Sigma = 0$ as the lines of contact of mating teeth with the phantom rack are then parallel and there is, in general, backlash in the condition of full-depth engagement of the gears. This difference between crossed helical gears and parallel-shaft helical gears must be taken into account in detail design.)

Blank Diameters

Adjacent teeth of a rack of normal pitch p_n, set with the tips of the teeth inclined at angle σ to the axis of the gear, intersect any plane containing the axis at spacing p_n cosec σ and this is therefore the axial pitch of the teeth of a gear conjugate to the rack. Similarly, the spacing of intersections of adjacent teeth with any plane perpendicular to the axis is $p_n \sec \sigma$ and this is therefore the transverse spacing of the teeth on the cylinder that " rolls " with the rack, i.e. the meshing cylinder. If the rack is a basic rack then the meshing cylinder is also called the " reference cylinder " and its diameter is

$$d_f = (p_n/\pi)\, t \sec \sigma$$

Note that σ is the helix angle of the gear teeth at the reference cylinder. It is defined unambiguously in terms of the normal pitch p_n of the standard rack with which the teeth are conjugate and of their axial pitch p_a (which is directly measurable), by $\sin \sigma = p_n/p_a$.

The blank diameter d_b is usually greater than d_f and the relation between the two may be expressed as

$$d_b = d_f + V\,(p_n/\pi) \quad . \quad . \quad . \quad (9)$$

where V is a number (usually positive).

In old systems of design, V was a constant (in the Brown and Sharpe system it is 2). This is unnecessarily restrictive as in the design stages V may have any value within a range limited by the need on the one hand to avoid teeth with sharp crests and on the other hand to avoid teeth in which any useful part of the involute profile has been lost by sinking the cutter too far inside the base cylinder. A range of V that is satisfactory in this respect and at the same time gives enough flexibility to avoid any need ever to use any cutter or non-standard pitch is defined by stating that

V may have any value that is

$$\left.\begin{aligned} &(a)\ \text{less than } 4 - 10/t \sec^3\sigma \\ &(b)\ \text{greater than } 1 + 20/t \sec^3\sigma \end{aligned}\right\} \quad . \quad (10)$$

In old-fashioned phraseology a gear for which V differed from 2 was said to be " corrected." In less ancient nomenclature it is said to have a " modified addendum." Neither of these terms nor any other is either necessary or desirable ; they all have the objection of tacitly implying some special virtue in the case $V = 2$, whereas there is none but antique interest.

In the past certain combinations of " correction coefficients " (values of V) were reputed to have advantages over certain others, but those claims have died for lack of technical justification. High values of V are slightly preferable to low values and this may be remembered where there is choice.

The higher the value of $(V_1 + V_2)$ in a pair of straight-tooth spur gears or crossed helical gears of given diameters, the higher the surface-stress limitation on load-capacity and

this is worth remembering in design. In the case of helical gears to work with axes parallel, this effect is negligible.

Design of Crossed Helical Gears*

In general, design of crossed helical gears is not beset by any severe restrictions. There is no one and only solution to any ordinary design problem ; there is no ideal solution nor even a best solution and so there is no textbook method of solving any problem.

In parallel-axis gears, the ratio of the diameters is approximately the reciprocal of the velocity-ratio ; in crossed-axis gears there is no essential relation between the diameter-ratio and the velocity-ratio. This is very convenient in any case where conditions outside the gear teeth themselves impose limits on the diameter-ratio as these can be observed without restriction on the velocity-ratio. Examples of external restrictions are upper limits on tip diameters to avoid fouling adjacent objects and lower limits on root diameters in the interest of shaft strength.

Where no external consideration prohibits it, approximate equality of the ratio of the tooth-numbers and the diameter-ratio gives minimum loss by friction by lengthwise sliding of the teeth. The velocity of such sliding is unaffected by the depth of the teeth and therefore by their normal pitch ; there is consequently no virtue in this respect in using teeth of very fine pitch.

The term " fine pitch " has a meaning only if particular diameters are in mind ; the real criterion of fineness of pitch is the number of teeth in the pinion. Selection of this number is the first step in solving the general design problem which is that of calculating the manufacturing dimensions of a pair of gears to have a specified velocity ratio (with a tolerance of a few per cent) and to work together at a specified centre distance (with a machining tolerance).

Design Procedure

(Slide-rule working is adequate.)—Given Centre distance C ; Shaft angle Σ ; Gear ratio R_g (± 3 per cent) ; Tooth form B.S. 436.

(1) Tentatively take $d=2C/(1+R_g)$

$$D=R_g d.$$

Then the approximate blank diameters and root-diameters are

$$d_b=d(15+7R_g)/(15+5R_g)$$
$$d_r=d(15+2{\cdot}5R_g)/(15+5R_g)$$
$$D_b=D(17+5R_g)/(15+5R_g)$$
$$D_r=D(12{\cdot}5+5R_g)/(15+5R_g)$$

If R_g exceeds 6, the value of d_r may be too small to permit of boring the gear for a shaft of adequate strength. The gear may then be made solid with the shaft and d_r should not be less than about $0{\cdot}1+C(0{\cdot}1+5/T)$ inches.

(2) If these diameters are acceptable for clearances and bores, take $\sigma_1=\sigma_2=\frac{1}{2}\Sigma$.

If not, find by trial values of d and D (noting that $d+D=2C$) that produce satisfactory blank diameters and root diameters.

(3) Determine approximate values of σ_1 and σ_2 from

$$\tan\sigma_1=(R_g d/D-\cos\Sigma)/\sin\Sigma$$
$$\tan\sigma_2=(D/R_g d-\cos\Sigma)/\sin\Sigma$$

Check $\sigma_1+\sigma_2=\Sigma$ and note that σ for the gear that is to be driven by its mate should preferably be less than 60 deg.

(4) Calculate

$$p_{n1}=2\pi C/[\sec\sigma_1+R_g\sec(\Sigma-\sigma_1)]t.$$

(5) Tentatively select a value of t between $(40/R_g-10/R_g^2)$ and $(30/R_g-20/R_g^2)$ but not less than $d^2n/2500$ unless the teeth are finished by hobbing, shaving or precision grinding in which cases the limit is $d^2n/10{,}000$.

(6) Applying tentative values of t in (4), try to find one that brings p_{n1} within 5 per cent of a standard pitch. If none can be found, take larger values of σ_1 in (4) until a satisfactory value of p_{n1} is found with a value of t within the limitations of (5).

(7) Take T as the nearest whole number to $R_g t$ and recalculate (4) with R_g replaced by T/t. If p_{n1} is within 5 per cent of a standard pitch, adopt that pitch as p_{n1}. If not, change T (within the tolerance on R_g) or change σ_1 until a satisfactory value of p_{n1} is found.

(8) Using the adopted standard pitch p_n, take p_{a1} as the next number above $p_n\operatorname{cosec}\sigma_1$ that can be expressed as the product of two numbers each less than 100.

Take p_{a2} as the next similar number below $p_n\operatorname{cosec}\sigma_2$.

(In the case of equal gears $p_{a1}=p_{a2}$ must be the number as described nearest to $p_n\operatorname{cosec}\sigma$.)

(9) Recalculate σ_1 and σ_2 by

$$\sin\sigma_1=p_n/p_{a1} \qquad \sin\sigma_2=p_n/p_{a2}$$

Check

$$\sigma_1+\sigma_2=\Sigma\pm 10 \text{ min.}$$

(10) Determine

$$t_e=t\sec^3\sigma_1 \qquad T_e=T\sec^3\sigma_2$$

(11)

Maximum $V_1=4-10/t_e$
Maximum $V_2=4-10/T_e$
Minimum $V_1=1+20/t_e$
Minimum $V_1=1+20/T_e$

Fig. 3—Twelve-tooth crossed helical gears meshing with axes at right-angles

Hence

Maximum $(V_1+V_2)=8-10/t_e-10/T_e$
Minimum $(V_1+V_2)=2+20/t_e+20/T_e$

(12) Let

$$V_c=2\pi C/p_n-t\sec\sigma_1-T\sec\sigma_2+4.$$

(13) If V_c lies within the permitted range of (V_1+V_2), the values of t, T, p_n, σ_1 and σ_2 may be adopted. If not, V_c must be brought within the range by a change in T or (t and T) or in σ_1 (and σ_2).

Then V_1 and V_2 may be given any of the values permitted by (11) that add up to V_c. Unless circumstances forbid, the following procedure is recommended.

(14) Make V_1 equal to its nearest permitted multiple of $0{\cdot}1$ to

$$\tfrac{1}{2}V_c+10(1/t_e-1/T_e)$$

provided that V_b-V_1 is then a permitted value of V_2. If not, make V_2 equal to its nearest permitted multiple of $0{\cdot}1$ to this and make $V_1=V_c-V_2$. (There is no point at this stage in considering finer steps than $0{\cdot}1$ in values of V_1 and V_2.)

(15)

$$d_b=(p_n/\pi)(t\sec\sigma_1+V_1)$$
$$D_b=(p_n/\pi)(T\sec\sigma_2+V_2)$$
$$\text{Check } C=\tfrac{1}{2}(d_b+D_b)-2p_n/\pi$$

Correct any small discrepancy here by appropriate adjustment of D_b.

(16)

$$L_1=tp_{a1} \qquad L_2=Tp_{a2}$$

The description of this procedure may seem in parts to be laboured. This is because an endeavour has been made to lay down precise instructions to cover every likely condition instead of adopting the usual and easier course of leaving the reader to overcome detail difficulties for himself.

(17) *Backlash.*—The condition of " no backlash," or the best practical approximation to it is necessary in some classes of gears in instruments, but it is a potentially dangerous condition in power-transmitting gears and is therefore to be avoided.

Every pair of gears should have a " designed backlash " b (of the order of $(0{\cdot}005$ to $0{\cdot}01)p_n$ which is the minimum clearance between mating tooth-flanks when held as far apart as other pairs of flanks permit with the gears meshed at the designed centre distance.

To provide for b, the tooth-thickness of each gear of a pair of is less than the nominal one corresponding to zero backlash by

$$\tfrac{1}{2}b\sec\text{ↀ}=\tfrac{1}{2}b\sec\psi_n \text{ (approx.)}$$

If the shaft angle Σ is changed by $\Delta\Sigma$ from the sum $(\sigma_1+\sigma_2)$ of the reference helix angles, the relative movement of mating tooth-flanks at any contact point on P_1P_2 (Fig. 2) is $q\Delta\Sigma$ in the direction P_2M and therefore $q\Delta\Sigma\cos$ ↀ in the normal direction P_1P_2. This relative movement is duplicated at the opposing sets of tooth-flanks. Hence the backlash between full-depth teeth at the shaft angle $(\sigma_1+\sigma_2)+\Delta\Sigma$ is

$$k=2[\Sigma-(\sigma_1+\sigma_2)]\,q\cos\text{ↀ}$$

After various substitutions, including ↀ$=20$ deg., this becomes, for B.S. teeth,

$$k=(v_1+v_2-4)(p_n/\pi)\cos\text{ↀ}\cot\text{ↀ}$$
$$[\Sigma'-\sigma'_1-\sigma'_2]/3440(\tan\sigma_1+\tan\sigma_2)$$
$$=p_n(v_1+v_2-4)(\Sigma'-\sigma'_1-\sigma'_2)/4200[\tan\sigma_1+\tan\sigma_2]$$

where the angle in the second bracket is in minutes.

The quantity k, which may be called the " basic backlash," between full-depth teeth, to be subtracted from the desired backlash b in determining the calipered thicknesses of the teeth. The tooth-thickness of both

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* *Notation.* (All lengths in inches.)
C—Designed centre distance.
d, D—Mean diameter of pinion and wheel.
d_b, D_b—Blank diameter of pinion and wheel.
d_t, D_t—Reference diameter of pinion and wheel.
d_r, D_r—Root diameter of pinion and wheel.
L_1, L_2—Lead of helices of pinion and wheel.
nN—Speed (revolutions per minute) of pinion and wheel.
p_{a1}, p_{a2}—Axial pitch of pinion and wheel.
p_n—Normal pitch of generating cutter.
p_{n1}—Tentative approximate value of p_n.
R_g—Gear ratio $=T/t$ (not less than 1).
t/T—Numbers of teeth in pinion and wheel.
t_e, T_e—Numbers of teeth in spur gears equivalent to pinion and wheel.
$t_e=t\sec^3\sigma_1$ $T_e=T\sec^3\sigma_2$
v_s—Sliding speed (feet per minute) lengthwise on teeth.
σ_{b1}, σ_{b2}—Base helix angles.
σ_1, σ_2—Helix angle at reference cylinder of pinion and wheel.
Σ—Shaft angle.
ↀ—Force angle.

Technical Contributors Section *(continued)*

pinion and wheel is made less than the nominal amount by $\frac{1}{2}(b-k)$ sec Ω or for B.S. teeth $0\cdot532\,(b-k)$ very nearly.

(18) A factor of some importance in connection with lubrication and load capacity of crossed helical gears is the sliding speed of the teeth in the direction of their length. This speed is given by

$$v_s \text{ (f.p.m.)} = 0\cdot26\sqrt{(d^2n^2+D^2N^2-2dnDN\cos\Sigma)}$$

where n=speed of pinion (r.p.m.) ; N=speed of wheel (r.p.m.) ; and d and D are in inches.

Example

It is required to determine manufacturing dimensions of gears to comply with the following conditions.

Centre distance $C=4\cdot83$in ;
Shaft angle $\Sigma=75$ deg.;
Gear ratio $R_g=3\cdot2\pm3$ per cent ;
Speed of pinion $r=2000$ r.p.m.;
Maximum permissible diameter of wheel, 7in.

Procedure.—(1) Tentatively

$$d=2\times4\cdot83/(1+3\cdot2)=2\cdot3$$
$$D=3\cdot2\times2\cdot3 \qquad =7\cdot35$$

As this exceeds the maximum permissible diameter of the wheel, that diameter is the controlling influence.

From (5) t tentatively lies between

$$40/3\cdot2-10/3\cdot2^2=11\cdot5$$

and

$$30/3\cdot2-20/3\cdot2^2=7\cdot4 \text{ say } 10 \text{ and } T=32.$$

Then from (1)

$$D_b/D=(17+5R_g)/(15+5R_g)$$
$$D=(17+16)/(15+16)=1\cdot06 \text{ (approx.)}$$

(2) Hence

$$\text{Maximum } D=7/1\cdot06=6\cdot6 \text{ (approx.)}$$

or say

$$D=6\cdot5$$

Then

$$d=2C-D=3\cdot16.$$

(3) $\tan\sigma_1=(3\cdot2\times3\cdot16/6\cdot5 - \cos 75 \text{ deg.})/\sin 75 \text{ deg.}=1\cdot34$

whence

$$\sigma_1=53 \text{ deg. } 15 \text{ min.}$$

$\tan\sigma_2=(6\cdot5/3\cdot2\times3\cdot16 - \cos 75 \text{ deg.})/\sin 75 \text{ deg.}=0\cdot4$

whence

$$\sigma_2=21 \text{ deg. } 45 \text{ min. and } \sigma_1+\sigma_2 = 75 \text{ deg. as required.}$$

(4) $p_{n1}=2\pi\times4\cdot83/(\sec 53 \text{ deg. } 15 \text{ min.} + 3\cdot2 \sec 21 \text{ deg. } 45 \text{ min.})t=5\cdot98/t$

(5) A value $t=10$ has been tentatively proposed and this is satisfactorily high in that $d^2n/2500=3\cdot36^2\times2000/2500=9$.

(6) Trying values of t near to 10 in (4) it is found that if $t=12$, $p_n=0\cdot543$ and this is within 5 per cent of the standard pitch $0\cdot5236$.

(7) $T=11\times3\cdot2=35\cdot2$ say 35 and $R_g = 35/11=3\cdot18$.

Retrial of this in (4) leads to no significantly different result.

(8) $p_{a1}=0\cdot5236 \operatorname{cosec} 53 \text{ deg. } 15 \text{ min.}$
$=0\cdot652$ say $0\cdot656$

$p_{a2}=0\cdot5236 \operatorname{cosec} 21 \text{ deg. } 45 \text{ min.}$
$=1\cdot413$ say $1\cdot41$

(As $652=4\times163$ and as 163 is a prime number, an alternative is required and as $656=16\times41$, this is adopted.)

As $1413=9\times157$ and as 157 is a prime number, an alternative is required and as $1410=30\times47$, this is adopted.

(9) $\sin\sigma_1=0\cdot5236/0\cdot656=0\cdot797$,
whence $\sigma_1=53$ deg. 0 min.
$\sin\sigma_2=0\cdot5236/1\cdot41=0\cdot371$,
whence $\sigma_2=21$ deg. 45 min.

Here $\sigma_1+\sigma_2=74$ deg. 45 min. instead of 75 deg. The necessary adjustment may be effected by changing p_{a2} to $0\cdot5236/\sin 22 \text{ deg.}=1\cdot40$.

(10) $t_c=11 \sec^3 53 \text{ deg. } 0 \text{ min.}=50\cdot5$
$T_c=35 \sec^3 22 \text{ deg. } 0 \text{ min.}=44.$

(11) Maximum $V_1=4-10/50\cdot5=3\cdot8$
Maximum $V_2=4-10/44=3\cdot77$
Minimum $V_1=1+20/50\cdot5=1\cdot4$
Minimum $V_2=1+20/44=1\cdot46$
Maximum $(V_1+V_2)=7\cdot57$
Minimum $(V_1+V_2)=2\cdot86$

(12) $V_c=2\pi\times4\cdot83/0\cdot5236$
$-11 \sec 53 \text{ deg. } 0 \text{ min.}$
$-35 \sec 22 \text{ deg. } 0 \text{ min.}+4=5\cdot93$

(13) As V_c lies within the permitted range of (V_1+V_2) the foregoing tentative values may be adopted.

(14) $V_1=5\cdot93/2+10\,(1/50\cdot5-1/41)$
$=2\cdot965-0\cdot046=2\cdot92$ say $2\cdot9$.
This is within the permitted range
$V_2=V_c-V_1=5\cdot93-2\cdot9=3\cdot03$.
This is within the permitted range

(15) $d_b=(1/6)\,(11 \sec 53 \text{ deg. } 0 \text{ min.}+2\cdot9)$
$=3\cdot528$
$D_b=(1/6)\,(35 \sec 22 \text{ deg. } 0 \text{ min.}+3\cdot03)$
$=6\cdot800.$

Check

$$C=\tfrac{1}{2}(3\cdot528+6\cdot800)-2/6=4\cdot833.$$

To bring C to the prescribed $4\cdot83$, the value of D_b is reduced by $2(4\cdot833-4\cdot83)=0\cdot006$, i.e. $D_b=6\cdot794$.

(16) $L_1=11\times0\cdot656=7\cdot216$
$L_2=35\times1\cdot40=49\cdot0.$

Note. The value $D_b=6\cdot794$ is suitably less than the prescribed $7\cdot000$. If it were desired to work nearer to this limit, the appropriate value of V_2 would be obtained from

$$7=(1/6)(35 \sec 22 \text{ deg. } 0 \text{ min.}+V_2)$$

or

$$V_2=42-35 \sec 22 \text{ deg. } 0 \text{ min.}=4\cdot2.$$

This is beyond the permitted maximum of $3\cdot77$. With the other dimensions used here Max $D_b=(1/6)\,(35 \sec 22 \text{ deg. } 0 \text{ min.}+3\cdot77)=6\cdot92$. The corresponding value of V_1 is $V_c-3\cdot77=2\cdot16$ and then $d_b=(1/6)\,(11 \sec 53 \text{ deg. } 0 \text{ min}+2\cdot16)=3\cdot41$.

Facewidth.—In the lower left-hand corner of Fig. 2 is an axial view of gear 2 ; the point G_2 is the intersection of the line of action with the tip cylinder of the gear and is therefore the upper limit of the path of contact. G_2H_2 is the perpendicular from G_2 onto A_2B_2 and G_2H_1 is the perpendicular from G_2 onto A_1B_1.

OM_2 is the perpendicular from the axis to the plane of P_2G_2 and A_2B_2. This plane contains a normal (P_1P_2) to a tooth-flank on gear 2 and also a parallel to its axis. It is therefore tangential to the base cylinder.

Hence $OM_2=\frac{1}{2}d_{02}$

Also

$OP_2=\frac{1}{2}d_{m2}=r_{m2}$, given by (6)

Hence

$$H_2G_2=\tfrac{1}{2}\sqrt{(d_{b2}^2-d_{02}^2)}-\tfrac{1}{2}\sqrt{(d_{m2}^2-d_{02}^2)}$$

Now the line of action is inclined to the axis of each gear at the angle 90 deg. $-\sigma_0$ and so

$$P_2G_2=H_2G_2\sec\sigma_{02}$$

Hence

$$P_1G_2=P_2G_2-P_1P_2=H_2G_2\sec\sigma_{02}-e\operatorname{cosec}\Omega_n$$
$$O_1H_1=O_2M+P_1H_1=O_2H\sec\sigma_{m1}$$
$$+P_1G_2\sin\sigma_{m1}$$
$$=q\sec\sigma_{m1}+P_1G_2\cos\Omega_n\sin\sigma_{m1}$$
$$=q\sec\sigma_{m1}+(H_2G_2\sec\sigma_{02}$$
$$-e\operatorname{cosec}\Omega_n)\cos\Omega_n\sin\sigma_{m1}$$

This is the distance, measured parallel to the axis of gear 1, of the extreme contact-point G_2 from the common perpendicular to the axis.

$$O_2H_2=P_2H_2-P_2O_2$$
$$=H_2G_2\cot\sigma_{02}-O_2H\sec\sigma_{m2}$$
$$=H_2G_2\cot\sigma_{02}-q\sec\sigma_{m2}$$

This is the distance measured parallel to the axis of gear 2 of the extreme contact-point G_2 from the common perpendicular to the axes.

Similar expressions may be derived from the position of the other extreme contact-point defined by the tip-cylinder of gear 1.

In this way the minimum desirable distances of four end faces from the common perpendicular may be determined, but to follow this procedure is more laborious than is justified by the necessary degree of precision in the result.

A sufficiently accurate estimate of the necessary and useful facewidth of a crossed helical gear with B.S. teeth is afforded by

$$f_1=0\cdot9p_n\{(\overline{V}_1+0\cdot5)\sin\sigma_1+1\cdot2\cos\sigma_1$$
$$+\left[(V_1+V_2-4)\cos\Sigma\right]/3(\tan\sigma_1$$
$$+\tan\sigma_2)\cos\sigma_2\} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

where $\overline{V}$ means V_1 or $(4-V_1)$ whichever is greater and (V_1+V_2-4) means (V_1+V_2-4) or $(4-V_1-V_2)$ whichever is positive. The value of f_2 is obtained by interchanging suffixes 1 and 2 in (10).

This formula includes an extension of the length of tooth-root by about $\frac{1}{2}p_n$ beyond each normal plane containing an end of the track of contact on the flank.

In the particular case examined, this formula gives

$$f_1=0\cdot9\times0\cdot524[3\cdot4\times0\cdot8+1\cdot2\times0\cdot6$$
$$+1\cdot93\times0\cdot26/3(1\cdot325+0\cdot4)\,0\cdot93]=1\cdot6$$
$$f_2=0\cdot9\times0\cdot524[3\cdot53\times0\cdot37+1\cdot2\times0\cdot93$$
$$+1\cdot93\times0\cdot26/3(1\cdot325+0\cdot4)0\cdot6]=1\cdot2$$

or say $1\cdot75$in for the pinion and $1\cdot25$in for the wheel.

Tooth Thickness.—The gear-tooth caliper settings for B.S. crossed helical gears to have normal backlash equal to b are

Thickness
$$g_1=(0\cdot321V_1+0\cdot744)\,(p_n/\pi)-0\cdot532\,(b-k)$$
Height
$$h_1=(0\cdot442V_1-0\cdot136)\,(p_n/\pi)$$

and the corresponding expressions for g_2 and h_2.

In the particular case examined above, assuming the desired backlash to be $0\cdot006$in and noting that $k=0$ since $\Sigma=\sigma_1+\sigma_2$,

$g_1=(0\cdot321\times2\cdot9+0\cdot744)/6-0\cdot532\times0\cdot006$
$=0\cdot276$
$h_1=(0\cdot442\times2\cdot9-0\cdot136)/6=0\cdot191$
$g_2=(0\cdot321\times3\cdot03+0\cdot744)/6-0\cdot532\times0\cdot006$
$=0\cdot283$
$h_2=(0\cdot442\times3\cdot03-0\cdot136)/=0\cdot200$

Note on Load Capacity of Crossed Helical Gears

Data on the load capacity of crossed helical gears in service is less extensive

than for worm gears. The nominal point contact of the former suggests a much lower load capacity than that of similarly dimensioned worm gears in which contact between two mating teeth extends nominally over a line. The difference in load capacity is less than this comparison might suggest, first, because crossed-helical gear contact, even though starting as point-contact, soon develops into line contact by conformation of the softer material to the harder and secondly because worm-gear contact is not always so extensive as elementary theory might suggest.

A convenient method of expressing the load capacity of crossed helical gears is to say that it may be taken as some fraction of that given by British Standard 721 for worm gears of the same major dimensions. The fraction has progressed with time from one-tenth to one-quarter. On test, however, crossed helical gears have shown load-capacity exceeding the B.S. rating for comparable worm gears. In these tests the number of teeth in the softer gear was an integral multiple of that in the harder gear and this is advantageous as each soft tooth touches the same hard tooth in every revolution and so good " bedding " is possible despite imperfection in the form or spacing of the hard teeth.

It seems reasonable therefore to rate crossed helical gears at one-quarter of the load capacity of the corresponding worm gears unless the gear-ratio is a whole number in which case the ratio is one-half. (This latter leaves a " factor of safety " of something over 2 on the basis of the test-results mentioned above.)

The process of " bedding-in " produces more backlash in crossed-helical gears than in worm gears ; in some circumstances this might be objectionable but in most cases it is not. In such cases there is some advantage in extending the normal running-in process to include a gradual increase in tooth-load to about $1\frac{1}{2}$ times the working maximum for about a thousand revolutions of the soft gear. The maximum contact stress in normal running is then less than the yield-stress associated with plastic deformation during running-in and the probability of pitting is therefore reduced.

Special Applications of Crossed Helical Gears

Crossed helical gears are sometimes used in conditions that preclude " running-in " after installation. For example, the camshaft drive in an internal combustion engine is subjected to maximum cyclic fluctuation of torque when the engine is running even at low speed and even under very light load ; moreover the sliding speed of the gear teeth may be over 1000 f.p.m. Nevertheless, in spite of the severity of the conditions and in spite of underestimates of the real tooth-loading, crossed helical gears have been successfully used in these circumstances. In other cases there have been failures generally due partly to underestimates of the loading, partly to the use of an inferior combination of gear materials, partly to inferior quality of gear teeth in spacing or finish, partly to inadequacy of lubrication and partly to lack of a " running-in " period.

In the absence of such an unfavourable combination of circumstances, crossed helical gears designed as described above can give good service if made in (steel)/(bronze) or (casehardened steel)/(casehardened steel) or (cast iron)/(cast iron). Very smooth finish of the teeth of the harder member is important and, especially where the speed is high, eccentricity and tooth-spacing errors must be minimised.

Motor Vehicle Noise Measurement

By D. W. ROBINSON,* W. C. COPELAND* and A. J. RENNIE*

Subjective tests are described in which noisiness judgments on passing vehicles were related to the objective readings of sound level meters with different frequency weighting networks. By classifying the vehicles according to type reasonable correlation was obtained with the readings using the I.E.C. A*-weighting. The residual spread is discussed in relation to the results of other investigations. Some experiments on the effect of obstructions near the test site on the readings of sound level meters are also described.*

THE regulation of motor vehicle noise entails as a first essential a satisfactory method of measurement, for without this any attempted enforcement of legislation is likely to lead to ambiguity or offences against common sense, and hence to injustice. By a satisfactory method of measurement is meant one which will give reproducible results at will for any given vehicle and which is representative of the noise actually emitted in the normal driving of the vehicle. Three factors are involved : the specification of suitable vehicle test conditions ; the acoustical nature of the testing site ; the choice of meter, which should ideally measure the noise in a way which accords with the judgments of human observers. A draft recommendation embodying these principles is now being prepared by the International Standards Organisation to supersede, it is hoped, some of the less satisfactory practices at present in force in different countries. This recommendation should bring about a much-needed uniformity in test methods (so facilitating the interchange of information) and provide a suitable basis for the drafting of legislation or regulations for the control of motor vehicle noise in individual countries.

This paper is concerned with the last two of the three factors mentioned above, and presents some experimental data relating to the proposed test method. Meanwhile extensive tests carried out by the Motor Industry Research Association in association with the Ministry of Transport have shown that the vehicle test conditions proposed by the I.S.O. are in general realistic and satisfactory in operation. Most of the questions currently under consideration by the I.S.O. have been investigated in various laboratories for well over twenty years, and one may ask why finality has not been reached before. So far as this country is concerned, a major investigation of motor vehicle noise measurement problems was undertaken by the National Physical Laboratory in the years 1935–37[1,2] on behalf of the Ministry of Transport, and led to the development of an objective noise meter[3] specially adapted to read the loudness level of the impulsive sounds characteristic of motor vehicle exhausts. The implementation of the reports referred to was impeded, largely as a result of the outbreak of World War II, and when interest in the matter was afterwards revived by the Ministry of Transport a new situation presented itself. First " Davis's " meter had not met with acceptance for loudness measurement in any standardisation circles, where interest had become centred more on methods of calculation based on spectrum analysis ; moreover the instrument was not available commercially. Secondly, the desirability of interchange of results at the international level had grown in relative importance and has since been taken up, as already mentioned, by the I.S.O. In almost all countries which had at the time (1956) regulations for motor vehicle noise, the sound level meter was specified as the measuring instrument. Thirdly, the International Electrotechnical Commission then had in hand the revision of sound level meter specifications, which created the likelihood of an internationally agreed instrument within the time-scale of the I.S.O. discussions and which would do away with the untidy situation in which somewhat different specifications existed in different countries (principally U.S.A. and Germany) for sound level meters.

In this situation the work of the I.S.O. would have been held up for an extensive period unless the sound level meter could be accepted ; Davis's meter, for example, would not have been internationally accepted without extended trials in various countries. At the same time, serious limitations of the sound level meter are recognised†, principally that it does not in general indicate as high as a true loudness measurement, the shortfall amounting to as much as twenty phons in the case of very impulsive sounds. Whether such large errors would result with vehicles on the road to-day, and whether by some adjustment (e.g. choice of frequency weighting network or subclassification of vehicles) a reasonably satisfactory method of using the sound level meter could nevertheless be arrived at were the questions facing the I.S.O. working group in 1959. The work described in this paper was undertaken as a contribution to the reply to these questions.

The reasons for accepting the sound level meter at the present time are purely practical : first, the existence of an agreed specification and secondly, its compactness and portability—features of great importance for everyday vehicle noise measurement. More sophisticated measuring instruments consisting of spectrum analysers providing input data for well-developed calculating procedures for loudness are extensively used in scientific investigations of motor vehicle noise. At present, however, no equipment of this type is capable of giving direct readings.

Subjective Experiments

Much work has been done on the loudness criterion applied to vehicle noise, notably the investigations by Kaye and Dadson,[2] Callaway,[4] and Rademacher,[5]. Loudness judgments, however, require laboratory listening conditions, in which a reference sound can be accurately set up as a standard of comparison. The gain in experimental precision may be offset by some loss of realism in the listening situation.

* Applied Physics Division, National Physical Laboratory.

† See, for example, D. B. Callaway, *Trans. S.A.E.*, **62**, 151 (1954), quoting a 1950 S.A.E. report " That noise meters complying with A.S.A. Standard 24.3-1944 gave test results which showed extremely poor correlation with loudness and annoyance judgment tests by human observers."

Technical Contributors Section (*continued*)

conversely, to listen to actual passing vehicles makes it impracticable to present an accurate and adjustable yardstick for comparison ; in such tests an absolute rating scale has to be employed and it is only possible to discriminate six, seven or perhaps eight points on such a scale.

Callaway[4] has shown, however, that a very high correlation is obtained between computed loudness and seven-point loudness rating scale judgments. For the purposes of the experiments described below, the absolute loudness level of the test vehicles was not determined. Our primary object was only to compare the readings of sound level meters using different frequency weighting networks with an appropriate subjective rating, for normal traffic on a suitably chosen road ; to observe which network produced the best correlation ; and to form an estimate of the errors likely to be incurred in practice.

The frequency weighting networks in question are those designated *A* and *B* in the I.E.C. Recommendation for Sound Level Meters (differing slightly from those in the American Standard ASA Z24.3-1944). These networks introduce a progressively increasing attenuation of the frequencies below 1000 c/s, greater in the case of *A* and *B*. They were originally introduced to represent, in a simplified form, the sensitivity curves of the human ear at the 40 phon and 70 phon loudness levels respectively. Latterly, however, it has become recognised that the use of the different networks outside the range of intensity for which their use was originally envisaged may lead to better results.

To obtain results for traffic under normal driving conditions and in a suitable acoustical environment, a survey of various main road sites was undertaken on our behalf by officials of the Ministry of Transport. In order to ensure a fairly wide range of noisiness a main road site with an up-gradient was sought. The latter feature, especially in the case of commercial traffic, is favourable for the purpose as the gear and speed adopted by drivers vary markedly with the vehicle load. The site finally selected was on the A23 (London–Brighton) about 30 miles south of London, on the southbound carriageway (Fig. 1). The road here is a fairly straight section of 24ft (7·5m) dual two-lane carriageway with a good surface, and an up-gradient of 7 per cent (1 in 14) in the southbound direction. The two carriageways are separated by a central reservation about 30ft (9m) wide planted with low bushes and shrubs. The nearside verge is fairly smooth grassland about 30ft (9m) wide, bounded by a low hedge. The measuring position was taken to be 23ft (7m) from the mid-line of the nearside traffic lane, at which a microphone was set up at a height of 4ft (1·25m).

The microphone was connected to a calibrated amplifier and high-fidelity tape recorder situated in a mobile laboratory van parked on the verge about 40 metres north of the microphone. Between the microphone and the van nineteen listeners (fifteen male and four female), were seated in a row about 1m apart, each listener being 7m from the mid-line of the traffic lane. The listeners were effectively screened from view of oncoming drivers by the laboratory van. They were members of the staff of the Ministry of Transport, National Physical Laboratory, Motor Industry Research Association and other organisations, and with few exceptions, had no previous experience of subjective judgments. The listeners recorded on prepared forms their subjective estimates of the noisiness of passing vehicles, using a six-point rating scale. Selection of the vehicles was made by an additional observer who gave cue signals to the listeners and to the operator in the mobile laboratory. He also recorded the vehicle description. A further observer operated a radar-type speed meter.

The rating by which the listeners judged the noisiness was as follows :

A	*B*	*C*	*D*	*E*	*F*
—	Quiet	Acceptable	Noisy	Excessively noisy	—
0	2	4	6	8	10

Only the verbal versions of the noisiness categories appeared on the test sheets : the numerical values in the lower row were adopted later to facilitate the data handling. No specific description was assigned to categories *A* and *F*, which the listeners were instructed to regard as extremes providing a baseline for the intermediate categories. Some 20 per cent of the recorded judgments were interpolated between adjacent categories, and were assigned the appropriate odd number. Instructions to the listeners were given verbally and were kept as brief as possible, avoiding reference to hypothetical listening situations and to the possibility of divergent criteria of judgment, with the object that the judgments should be made so far as possible on the received noise levels irrespective of the speed or gear in which the vehicles passed.

During the course of four hours listening the numbers of vehicles judged were : cars 129 ; commercial vehicles sixty-eight ; motor-cycles twenty-eight. The number of motor-cycles on the A23 during the day of the tests was disappointingly small. A number of supplementary runs was therefore arranged by Ministry of Transport drivers. Some additional runs with cars were also

Fig. 1—General view of roadside listening tests

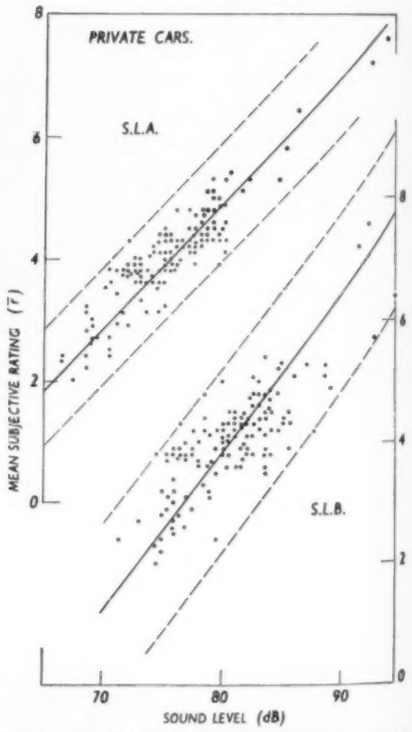

Fig. 2—Correlation of subjective rating with sound levels *A* and *B*, private cars

made to increase the range of noisiness at both extremes. The relation between noisiness and speed was markedly different for the private and commercial traffic respectively. In the former case, considering the traffic in groups at 10 m.p.h. intervals, the average noisiness increased uniformly with speed indicating the general use of top gear. The commercial traffic, however, was noisiest in the highest and lowest speed brackets and quieter in the intervening ranges reflecting the use of low gears at the lower speeds by the more heavily laden vehicles.

The tape recordings were subsequently played back in the laboratory, calibrating signals having been interpolated at intervals during recording to control the response characteristic and gain. The play-back amplifier was provided successively with weighting networks corresponding to the *A* and *B* networks of the draft I.E.C. recommendation for sound level meters‡, and the output was connected to a high-speed level recorder adapted to read "quasi-r.m.s." The microphone used was a condenser type (WE640AA) arranged with axis vertical. Maximum overall sound levels were read off the level recorder charts to the nearest 0·5 dB.

The subjective judgments were interpreted on a numerical scale as described above and the averages and standard deviations calculated. Individual judgments ranged from 1 to 9, the majority of the listeners using a range of six or seven points. Figs. 2, 3 and 4 show the relation between average subjective noisiness and sound level with *A* and *B* weightings, respectively for motor-cars, commercial vehicles and motor-cycles. Bearing in mind the object of the experiments, namely to test the relative validity of *A* and *B* sound level indications, the average subjective ratings have been regarded as the independent variable ($\bar{r}$) and the meter readings as dependent variables (y). The regression of y on $\bar{r}$ has been calculated for each case and the resulting straight lines of best fit are shown in the figures. The spread of the meter readings is shown by the broken lines which are drawn parallel to the line of best fit so as just to enclose all the observations.

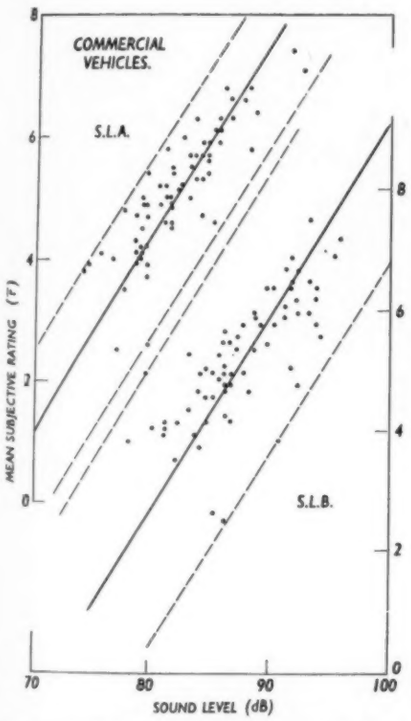

Fig. 3—Correlation of subjective rating with sound levels *A* and *B*, commercial vehicles

Comparison of the figures shows that for each class of vehicle the spread of observations is less with weighting network *A* than *B*, and for reasons discussed below it is believed that the advantage of the *A*-weighting is actually somewhat greater than the figures show. The results are considered satisfactory for private cars and commercial vehicles, for which an adequate sample was obtained. As regards motor-cycles, insufficient results were obtained, and the relatively large spread is probably due in part to the fact that "motor-cycle" is too broad a classification for these machines.

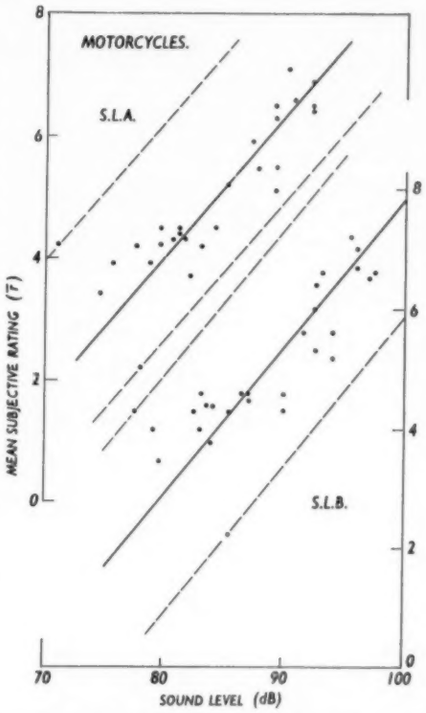

Fig. 4—Correlation of subjective rating with sound levles *A* and *B*, motor-cycles

It is important to note that very poor correlation would exist if all vehicles were grouped in one class.

From the regression lines, the meter readings corresponding to the steps of the rating scale may be read off, and the values so arrived at are given for convenience in Table I to the nearest 0·5 dB.

An interesting feature of these results is the difference between the rates of growth of meter reading (for given subjective intervals) of different classes of vehicles, which implies that a different criterion of judgment is applied. For example, of cars and commercial vehicles producing about 70 dB sound level (*A*) the former are judged the noisier, whereas at and above 90 dB the reverse is the case.

Statistical Discussion

Referring to Figs. 2, 3 and 4, it must be remembered that the width of the dispersion bands indicated by the broken lines is not wholly attributable to the fact that the meter readings do not correlate perfectly with subjective appraisal, since the ordinates of the plotted points (r) are themselves subject to uncertainty from two causes, namely the variability of judgments between observers, and the "error" of judgments by individuals. In principle these components of variance are separable by repeating the tests, but this was obviously impracticable in the present circumstances.

The total variability, however, could be calculated from the test records, and is represented by a standard deviation of 0·9 units on the numerical rating scale. Thus the standard deviation of each $\bar{r}$ was of the order $0{\cdot}9\sqrt{19} \div 0{\cdot}2$ (19 being the number of listeners). If an allowance is made for this subjective uncertainty by extracting the corresponding variance from the scatter about the regression lines, a corrected estimate of the residual spread is obtained, with the results shown in Table II.

Table II

Class of vehicle	Estimated residual spread of meter readings	
	A	*B*
Private cars	7·1	10·5
Commercial vehicles ...	8·1	13·3
Motor-cycles	14·2	15·2

Although it is strictly legitimate to extract only that part of the total variance which is attributable to the uncertainties of individual judgments, rather than the whole, the effect would be qualitatively similar, namely that the inherent advantage of weighting *A* over weighting *B* is somewhat greater than indicated by the widths of the dispersion bands in Figs. 2, 3 and 4. The overcorrected spreads estimated in Table II almost certainly represent the limitations of the sound level meter, except in the case of motor-cycles, for reasons already explained.

Comparison with Results of Analogous Investigations

The results of the investigation may be compared with those of Weber, Lauber and their associates[6] and with those of Andrews and Finch,[7] from two standpoints (i) the spread of meter readings about the respective regression lines and (ii) the absolute interpretation of the rating scales.

The Swiss investigation employed twenty vehicles of mixed types (four motor-assisted cycles, five motor-cycles, one tractor, seven private cars, three goods vehicles), each tested stationary and moving, and a team of twenty listeners using a four-point rating scale as follows :

Table I

Rating	Sound level meter reading (dB)					
	Weighting *A*			Weighting *B*		
	Cars	Commercial vehicles	Motor-cycles	Cars	Commercial vehicles	Motor-cycles
Quiet	65·5	72·5	71	73·0	78	76·5
Acceptable	75·5	79	79·5	80·5	84·5	84·5
Noisy	85·0	85·5	88	88·0	90·5	93
Excessively noisy	94·5	92	96·5	95·5	97	101

‡ TC29 Document 29 (Central Office) 32.

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1=gar nicht lästig (not at all objectionable)
2=nicht lästig (not objectionable)
3=lästig (objectionable)
4=sehr lästig (very objectionable).

Their scale was " intentionally kept as simple as possible and so constructed that, in addition, a clear judgment of the ' acceptability ' of a noise was possible " (1 and 2= acceptable, 3 and 4=unacceptable). Each vehicle noise was measured by means of sound level meters, with *A* and *B* weighting networks, the observers and microphone being some 7m from the near side of the vehicles, on an open test site.

Andrews and Finch[7] employed a ten-point " objectionableness " rating scale with a team of twenty-five listeners. The test material consisted of the noise of some twenty commercial vehicles recorded at a distance of 50ft (17m) and reproduced in the laboratory. In the instructions to their subjects, the scale was described as running " from a value of 1, which is quite inoffensive, to a value of 10, which is quite annoying. The basis of rating is objectionableness rather than loudness."

Table III summarises the correlation coefficients between subjective rating and sound level meter readings in the various investigations. It also shows the maximum deviations from the regression lines in decibels.

It is notable that measurements with the *A* weighting network were found in all the investigations to correlate better with the subjective rating than the corresponding values with *B* weighting network. The values of the maximum deviations in the present work and the Swiss investigation are comparable ; perhaps because the test noises were less variable§ the deviations observed by Andrews and Finch were appreciably smaller. Broadly, these data tend to confirm the conclusion already drawn regarding the margin of error implicit in the readings of *A*-weighted sound level meters.

When the results of the three investigations are compared from the standpoint of absolute significance of the rating-scale judgments, considerable divergences appear. In the first place, the entire range of sound levels (*A*) encountered in the Swiss work (52–84) is non-overlapping with that of Andrews and Finch (86–97), yet both have recorded judgments over almost the whole range of their respective rating scales. The range experienced in the present investigation was 66 to 97. Fig. 5 is a composite diagram illustrating the three scales in relation to sound level. For simplicity, the differences between the curves for different vehicle classes obtained in the present work have been ignored. The hatched area represents " unacceptability." The very variable boundary of the " acceptable " level is not readily explained except that some difference might be expected under the laboratory listening conditions used by Andrews and Finch. It seems clear that considerable further work will be needed to clear up this question, particularly as to whether listening conditions play a leading part, and another investigation has already been undertaken jointly by the National Physical Laboratory and the Motor Industry Research Association which may contribute to this.

TABLE III

Source	Type of vehicle	Vehicle condition	Correlation coefficient		Maximum deviation, dB			
			A weighting	*B* weighting	*A* weighting		*B* weighting	
					+	−	+	−
This paper*	Private cars	Moving...	0·94	0·79	4·5	5·0	6·1	5·4
	Commercial vehicles	Moving...	0·84	0·76	5·2	4·0	7·1	7·2
Swiss report	Mixed	Moving...	0·95	0·88	4·4	6·0	5·8	5·6
	Mixed	Stationary	0·94	0·91	6·0	5·2	3·8	6·0
Andrews and Finch	Commercial vehicles	Moving (recorded)	0·83	0·75	3·3	2·0	—	—

* Owing to the small sample of motor-cycles, values are omitted from the table.

TABLE IV—*Reading of Sound Level Meter Relative to that on Open Site* A

Site	Diesel- engined vehicle	Petrol-engined vehicle	Private car	Four-stroke motor-cycle	Mean (Four vehicles)
A	0	0	0	0	0
B	3·4	1·4	2·0	1·7	2·1
C	3·2	2·8	4·4	2·6	3·2
D	2·2	3·3	4·6	6·8	4·2

§ The total range of sound levels (*A*) was only 11 dB.

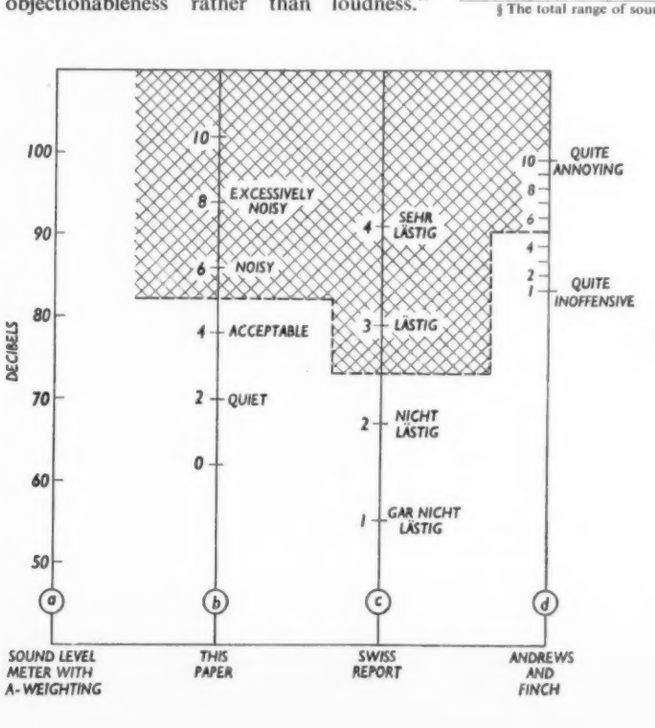

Fig. 5—Comparison of subjective and sound level scales

Acoustical Influence of Test Site

During its discussions, the ISO working group on traffic noise encountered some difficulty with the specification of a suitable test site. On the one hand, a specification in terms of overall acoustical requirements (for example, that the effect of the environment should be less than, say, 1 dB as compared with an ideal open space) offers no guide to those responsible for selecting such a site. On the other, it is difficult to describe in all particulars the surface, tolerable obstructions, flatness, &c., of sites which would guarantee such acoustical precision and which would not at the same time be excessively conservative in many cases.

To gain some idea of the likely effect of departures from the ideal, a number of tests was carried out on four sites in the Watford area ranging from a large open space to a quite confined roadway. Fig. 6 shows views of the locations chosen. For the purpose of the tests four vehicles (one diesel-driven goods vehicle, one petrol-driven goods vehicle, one private car and one four-stroke two-cylinder motor-cycle) were employed.

To establish the effect of acoustic environment, as distinct from other errors, it was essential to ensure that the noise emitted by the vehicles was repeatable. To this end each vehicle made from four to six test runs on each site under the driving conditions specified in the draft ISO recommendation. These consist of a constant speed approach, the gear and speed being determined by the engine rating, followed by full throttle opening as the vehicle reaches a line 10m in front of the microphone position. The throttle is closed again 10m after the microphone position. At each site the microphone was sited 7·5m from the centre of the vehicle track.

The repeatability of the readings on a given site under these conditions depends primarily on the driver complying with instructions and is then usually within 1 dB sound level (*A*). A few runs were omitted from the final averages when it was evident that the vehicle conditions had not been strictly correct. Two sound level meters were

Fig. 6—Effect of acoustical environment on measured sound level was tested at the four sites shown

used in the tests, one operated by National Physical Laboratory staff and the other by officials of the Ministry of Transport who collaborated in the experiment. The *A* weighting network was used in each case. The results are shown in Table IV for the individual vehicles, together with the mean. Each entry in the last column represents the average reading of the two sound level meters over the repeated test runs, so that the number of values contributing to each entry is of the order 40.

In general the trend of the results is as would be expected, increasing with the amount of obstruction. Moreover the uncertainty of the augmentation increases. The cause of the reversed trend of the diesel-engined vehicle results was not investigated. Whilst the results can only be regarded as typical and would no doubt differ in detail for other vehicles and other types of test site, it seems reasonable to conclude that a site such as *B*, with a major obstruction (two-storey semi-detached dwellings) on one side only, the buildings lying some 40ft from the vehicle track, would be inadmissible for accurate results.

On the other hand, for spot-checking of vehicles on the road, it would appear reasonable to use a site such as *B* (or even *C*) if no better could be found, provided that an appropriate margin were allowed over the value which would be permitted on an ideal site.

It is perhaps hardly necessary to add that site *D* would be quite unsuitable for any systematic noise measurements, but it was included in the tests only to provide, with the fairly good site *A*, a yardstick by which to compare the intermediate cases.

Conclusions

For the present, due to a variety of reasons, it is imperative for the standardisation of methods of measuring motor vehicle noise to accept the use of sound level meters (of adequate precision) notwithstanding the serious limitations of these instruments in comparing noises of varying impulsive character or having differing spectra.

Subjective tests in which a group of nineteen listeners rated the noisiness of 225 vehicles on a simple scale of acceptability showed that a reasonable correlation exists between the average judgment and the reading of a sound level meter provided the vehicles are classified, e.g. into private cars, commercial vehicles, &c. Moreover, the correlation is substantially better with weighting network *A* than *B*. Results for motorcycles were inconclusive owing to shortage of test material.

The advantage of the *A*-network over the *B* is confirmed by a Swiss investigation, in which the correlation with human judgments was found to parallel closely that in the present tests.

The absolute interpretation of the acceptability level in terms of sound level meter reading is considerably discordant in the two investigations. An American determination is still further discordant, but this result may be due to the different experimental conditions.

Experiments carried out on the acoustical influence of obstructions near a test site provide some guide to the choice of site required for precision purposes or for spot-checking on the road.

Acknowledgments

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Technical Contributors Section (*continued*)

Deflection of a Wohler Test Piece during Fatigue Cycling

By D. H. HUGHES, M.Sc.(Eng.),* and T. R. G. WILLIAMS, M.Sc., A.I.M.*

The fracture of a component due to fatigue cycling involves three stages, namely crack initiation, crack propagation and rapid tearing. The separation of crack initiation from crack propagation is of importance not only in studies of the mechanism of fatigue, but also in such practical problems as the assessing of cumulative fatigue damage. Fatigue fractures in notched test pieces of mild steel which have been stressed in a Wohler machine reveal a considerable amount of shiny cleavage structure in the tensile portion of the fracture. This work was undertaken to investigate the effect of varying amounts of fatigue cycling on the transition temperature of a notched fatigue test piece of mild steel.

TO separate the effect of fatigue before crack formation from that due to the combined effect of fatigue cycling and changes in notch geometry due to cracking, a method of measuring the onset of a fatigue crack was required. It was decided to use the change in vertical deflection of a Wohler test piece as a guide to crack initiation on the assumption that a significant change in deflection would correspond to the formation of a crack of sufficient size to alter the stress level in the test piece.

Experimental Work

An apparatus was constructed which recorded the vertical deflection of the free end of a Wohler test piece during its fatigue life. Fig. 1 is a diagram of the apparatus developed. Two photocells were used to measure the amount of light passing over the specimen and the signal obtained was taken, via a cathode follower system, to a chart recorder. The material used was a normalised mild steel of the following composition and properties :

C Per cent	Si Per cent	Mn Per cent	S Per cent	P Per cent
0·27	0·21	0·76	<0·6	<0·06

Yield stress	U.T.S.	Per cent E	Per cent reduction in area	Ageing index
18·5 tons per square inch ...	31·0 tons per sq. in	25	62	1·13

(13 per cent increase in yield stress was obtained after a 10 per cent extension and ageing for twenty-four hours at 100 deg. Cent.).

Fatigue cycling was applied in a rotating cantilever Wohler machine, and Fig. 2 is a drawing of the test piece used. A shallow notch profile was adopted in an effort to increase the extent of the crack initiation stage in fatigue.

Typical deflection curves obtained at varying stress levels are shown in Fig. 3. Three stages are observed in the deflection record ; the primary and secondary stages involving crack initiation, and the tertiary stage, crack propagation at an increasing rate up to fracture. When the various stages of deflection were examined in a family of graphs obtained with the same loading conditions, the tertiary stage was found to be of the same duration in all samples and of almost identical shape. Scatter in fatigue results was thus associated with the primary and secondary stages of crack initiation.

For a particular load level in fatigue testing a series of deflection graphs was recorded and from the results an average graph was constructed. With interaction tests of fatigue and transition temperature in the primary and secondary stages of fatigue, the test pieces were subjected to equal numbers of fatigue cycles, which were a fixed percentage of the average fatigue life at a particular load level. The transition temperature of the notched test pieces was measured both by a Tipper notched tensile test and an impact test in the Izod machine. In both

* Department of Mechanical Engineering, University of Southampton.

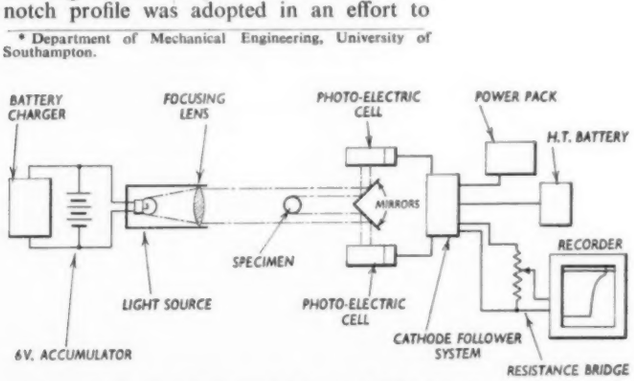


Fig. 1—Diagrammatic layout of deflection rig

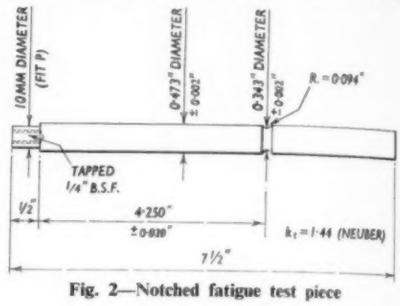


Fig. 2—Notched fatigue test piece

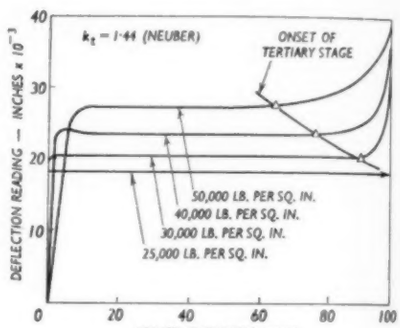
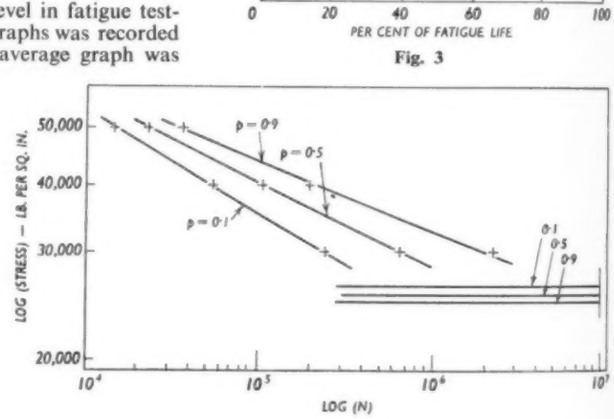

k_t = 1·44 (NEUBER)
ONSET OF TERTIARY STAGE
50,000 LB. PER SQ. IN.
40,000 LB. PER SQ. IN.
30,000 LB. PER SQ. IN.
25,000 LB. PER SQ. IN.
DEFLECTION READING — INCHES × 10^{-3}
PER CENT OF FATIGUE LIFE

Fig. 3

Fig. 4



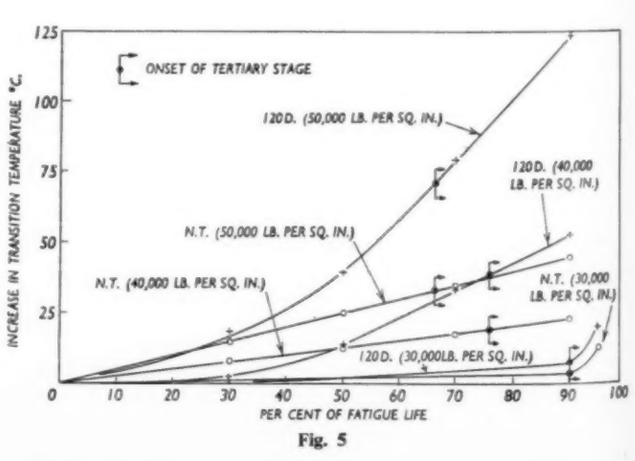

ONSET OF TERTIARY STAGE
120D. (50,000 LB. PER SQ. IN.)
120D. (40,000 LB. PER SQ. IN.)
N.T. (50,000 LB. PER SQ. IN.)
N.T. (40,000 LB. PER SQ. IN.)
N.T. (30,000 LB. PER SQ. IN.)
120D. (30,000LB. PER SQ. IN.)
INCREASE IN TRANSITION TEMPERATURE °C.
PER CENT OF FATIGUE LIFE

Fig. 5

tests the criterion for the transition temperature was that at which the first amount of "crystalline" fracture appeared. All the transition temperature tests were carried out immediately after completion of the fatigue cycling so that no strain ageing in addition to that experienced during fatigue cycling, would occur. For interaction tests, in the tertiary stage of fatigue, the test pieces were brought to the same deflection and the number of cycles corresponding to this deflection in the average fatigue life was recorded. Fig. 4 shows the P-S-N graph for the steel and Fig. 5 the results of the tests of interaction between fatigue cycles and transition temperature.

Discussion of Results

The results show that fatigue cycling, both up to and after the initiation of propagating fatigue cracks, can raise the transition temperature as measured by the Izod notched impact and notched tensile test. The higher the stress level in fatigue cycling, the greater the rise in transition temperature at both the crack nucleation and crack propagation stages. After fatigue cycling to small proportions of the total fatigue life the rise in transition temperature, as measured by the notched tensile test, tends to be the greater, but a crossover occurs at the later stages in fatigue life, and very large effects are shown in the Izod test results.

Conclusions

Fatigue stressing has raised the transition temperature of this steel and the amount of the increase is related both to the extent of the load level above the fatigue limit and the proportion of the fatigue life expended.

Flow Properties of ATK at Low Temperatures

By S. C. DODSON and A. G. C. FAIRMAN*

Some of the work done on ATK (Aviation Turbine Kerosine) at the B.P. Research Centre is described here. This work had two aims. The first was to measure the low-temperature performance of certain ATKs under various operating conditions in a rig simulating an aircraft fuel system. The second was to find a laboratory test which would reproduce the results obtained on the rig.

THE new jet and turboprop airliners now in service with world airlines cruise at much higher altitudes than their piston-engined predecessors. Sometimes, the temperature of the atmosphere at cruising height is as low as —75 deg. to —85 deg. Cent. It is essential, therefore, to select for these high-flying aircraft fuels that will flow satisfactorily at extremely low temperatures. The two materials in general use are Aviation Turbine Kerosine and Avaition Turbine Gasoline, usually referred to as ATK and ATG (or JP4) respectively. ATK closely resembles the fuel burnt in kerosine type domestic heaters, whilst ATG contains a high proportion of the more volatile materials normally found in gasoline. With both of these fuels every effort is made by the suppliers to remove suspended water, but icing of engine filters can still be a problem at low temperatures. The ice is derived from moisture which enters the fuel tank, through the fuel tank vent, during flight and probably also from the small amount of water which remains dissolved in fuel when supplied to the aircraft. To overcome this problem most types of aircraft are being fitted with fuel heaters so that the fuel is warmed before entering the filter. These heaters are also effective in preventing solid hydrocarbons from being deposited on engine filters.

This type of protection is not possible in the remainder of the fuel system, but precipitated ice is not expected to cause blockage either at the inlet to the tank booster pump or in the fuel pipes, since any difficulty of this kind can be overcome by incorporating a suitable additive into the fuel. The tank booster pump inlet and fuel pipes exposed to low temperatures are, however, vulnerable to blockage by precipitated hydrocarbons. Thus, the low temperature properties of the fuel itself are the limiting factors. The gasoline type aviation turbine fuel has good low temperature characteristics and does not precipitate appreciable quantities of solidified hydrocarbons at the lowest operational temperatures.

With Aviation Turbine Kerosines the situation is less satisfactory. The temperature at which they start to solidify is very close to the temperatures which may be reached in service and more information is required on their low temperature behaviour. It is also necessary to have a simple laboratory test which can be used for quality control testing and to set specifications. The laboratory test must be reproducible, simple to use, and correlated with service performance; otherwise a "safety factor" has to be applied which makes the specification unnecessarily restrictive and usually results in increased production costs for the material. In the case of ATK, an unnecessary restriction on low temperature performance would also reduce the quantity of ATK available from a given quantity of crude oil.

Work has been carried out at the BP Research Centre with the following aims:

(1) To measure the low temperature performance of a selection of ATKs under a variety of operating conditions in a rig representative of an aircraft fuel system.

(2) To find a laboratory test which reproduces adequately the rig results.

Some aspects of this work and its results are detailed in this article.

Rig Tests

(i) *Simulation of Operational Temperatures.*—Available data indicate that the minimum atmospheric temperature likely to be encountered at the flying altitudes of modern civil jet aircraft is —85 deg. Cent. However, temperatures below —75 deg. Cent. are met very infrequently and these are usually restricted to localised areas. In practice, if allowance is made for a reasonable temperature rise due to kinetic heating, the minimum effective ambient temperature to which an aircraft fuel system is likely to be subjected is —55 deg. Cent. The low temperature plant at the BP Research Centre was designed to give air temperatures of —65 deg. Cent., but in certain conditions temperatures as low as —70 deg. Cent. have been reached.

(ii) *Investigation of the Factors Affecting the Blockage at the Inlet to a Tank Booster Pump.*—For these tests an aircraft tank booster pump was mounted in a cylindrical tank, and the complete equipment was installed in the low-temperature cabinet as shown in Fig. 1. The assembly included instruments to measure flow rate and pressure and to record the temperature at various points in the fuel system. In each run the temperature of the fuel was reduced progressively; at intervals the pump was switched

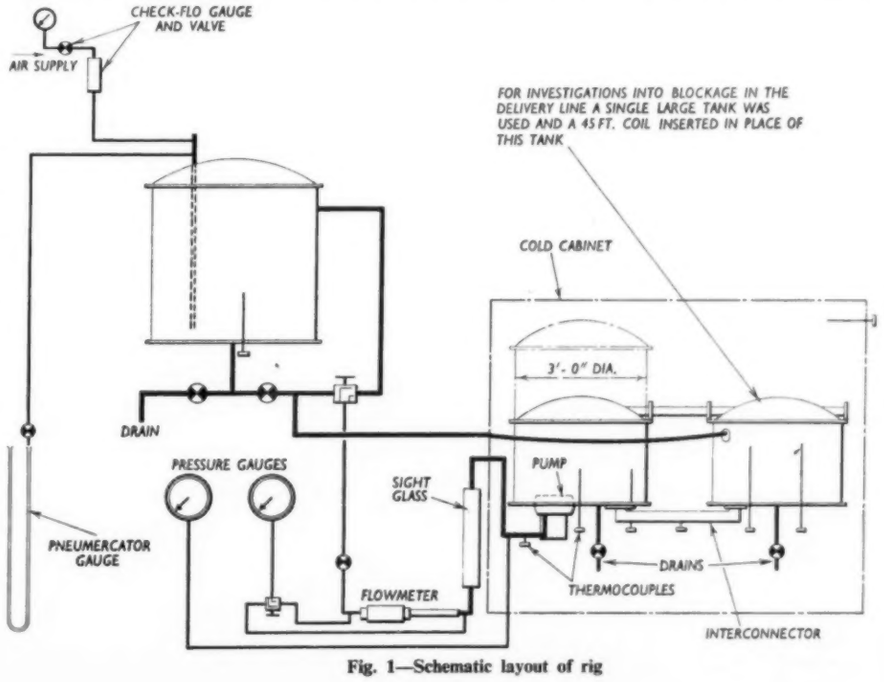


Fig. 1—Schematic layout of rig

*The British Petroleum Company, Ltd., Petroleum Division, B.P. Research Centre, Sunbury-on-Thames, Middlesex.

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on and the fuel flow rate was checked. Eventually, when the temperature of the fuel entering the pump approached the limiting value, the flow rate decreased rapidly. The variation in flow rate with temperature obtained with three typical kerosines is shown in Fig. 2; it will be noted that the flow was little affected by temperature until the limiting temperature was approached. The general slopes of the curves shown in Fig. 2 are reasonably representative of those obtained for all of the fuels tested, although

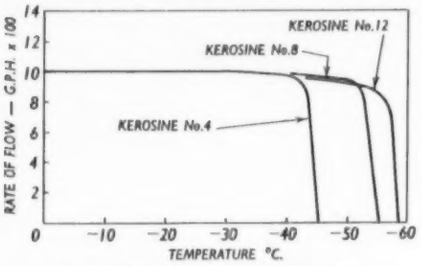


Fig. 2—Flow-temperature relationships

the temperature at which blockage occurred varied from one fuel to another. The repeatability of the test was checked and found to be satisfactory, and the effect of variations in the physical arrangement of the apparatus was investigated.

It was thought that two factors might be important in controlling the flow of kerosine into the pump at low temperatures, namely the mesh size of the booster pump screen and the head of kerosine above the pump; these were examined separately. In tests with ATKs of widely different characteristics it was found that within the range of mesh sizes used in service the booster pump screen had a negligible effect on the limiting temperature. The head of fuel above the pump was found to have a significant effect and, as shown in Fig. 3, a reduction of 1 deg. Cent. in the limiting temperature was obtained for an increase of 10in in head of kerosine. The kerosine used in these tests was a typical ATK produced from Middle East crude. Some variation in the limiting temperature with change in head was expected since it is known that kerosines, in common with other hydrocarbon fuels and lubricants, do not have a definite temperature at which they change from liquid to solid. In general, each

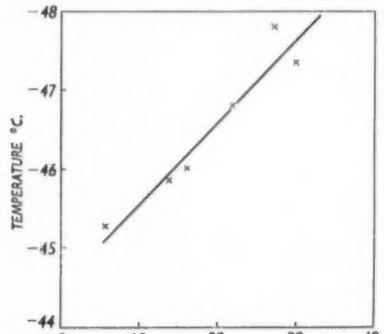


Fig. 3—Variation of pumpability limit with hydrostatic head

kerosine has a temperature at which solid material first begins to form, and as the temperature is further reduced the volume of solids increases and forms an openwork structure or matrix with the liquid fuel held in the interstices. This structure can be broken down if sufficient pressure is applied, and the effect of an increase in the head of fuel above the pump is to increase the pressure available to break the matrix structure at entry to the pump.

It is also known that movement of the fuel, such as would occur if the fuel were agitated continuously by stirring or by repeated tilting of the tank, would modify the matrix structure and maintain the kerosine in a more fluid condition. In modern jet aircraft, however, the flight conditions are such that very little movement is imparted to the fuel in the tank. Also, the lowest fuel temperatures are likely to occur towards the end of the flight when the level of the fuel in the tanks is low. Accordingly, the bulk of the tests in the rig were conducted under the most severe conditions likely to be encountered in service, that is, with a low fuel level and without fuel agitation. Seven ATKs with varying compositions were tested, and a range of pumpability limits from —45 deg. to —65 deg. Cent. was obtained (Table I).

TABLE I—*Limiting Temperatures for Pumpability at Various Operating Conditions*

(Limiting Temperature in degrees Centigrade)

	ATK	At entry to tank booster Pump	In delivery line (flight plan tests)	In delivery line (low pump delivery pressure)	In delivery line (short line)	Laboratory pumpability test
1		—	36·3	—	—	38·0
2		—	45·4	—	—	46·5
3		—	45·3	—	—	47·0
4		45·4	46·0	46·5	46·9	47·0
5		—	48·6	—	—	49·0
6		—	49·0	—	—	51·0
7		—	50·5	—	—	51·0
8		54·4	54·8	—	—	55·5
9		54·6	55·3	—	55·6	56·3
10		—	56·0	—	—	57·5
11		59·0	58·7	—	—	60·5
12		58·9	62·5	—	—	62·0
13		64·6	62·3	61·2	63·7	63·0
14		64·0	64·8	—	—	66·0

(iii) *Investigations of the Factors Affecting Blockage in the Delivery Line.*—In the tests to induce blockage at the inlet to the pump, it was found that the fuel lines inside the cold chamber needed to be wound with electric heaters and lagged in order to prevent blockage occurring. This emphasised the need for investigating the occurrence of blockage, by solidified fuel, of one of the more susceptible sections of an aircraft fuel system, namely lines which have kerosine lying stationary in them for part of the pumping cycle during flight.

Some aircraft have fuel systems which are so designed that fuel has to be pumped from tanks alternately in order to maintain a reasonable distribution between the tanks.

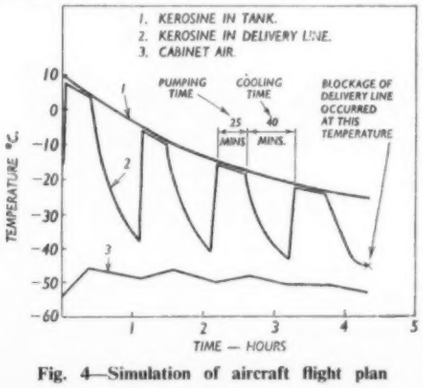


Fig. 4—Simulation of aircraft flight plan

In such a system lengths of fuel line are filled with immobile kerosine for some periods of the flight time. The effect of these conditions on the cooling rate of the kerosine is shown in Fig. 4.

The results shown in this Figure were obtained in the rig shown in Fig. 5. In this rig, blockage was induced in the 45ft length of 1½in bore aluminium alloy pipe on the delivery side of the pump. The air temperature in the refrigerated cabinet was first reduced to about —55 deg. Cent., then the kerosine under examination was introduced into the tank. A test routine of intermittent pumping was followed, so that at intervals the ATK was allowed to cool in the coil under static conditions.

In Fig. 4 the effect of the pumping cycle on the temperature of the ATK in the coil is shown clearly; it is apparent that in service the residence time of fuel in the pipe should be reduced to the minimum. In the test, blockage occurred after 4½ hours. If the pumping and non-pumping times were each reduced by half in the example shown, the temperature for cessation of flow would not be reached for at least seven hours. The temperature of the fuel in the tank can be seen to be falling at a reasonably slow rate, and if the fuel were pumped from the tanks continuously the fuel temperature in the pipe would approximate closely to the fuel temperature in the tank. Thus, by a slight alteration to a flight plan, the flying time before a dangerous state is reached would be extended considerably.

Fourteen ATKs, including the seven tested by the procedure described in section (ii) above, were also tested under these simulated flight conditions.

(iv) *The Effect of Booster Pump Delivery Pressure and Length of Delivery Line.*—The results obtained in the two sets of tests described so far were in close agreement. However, since the head of fuel above the pump was found to affect the temperature at which blockage at entry to the pump occurred, it followed that the agreement would not hold if greater heads of fuel were used. It was expected also that the length of the delivery line and the maximum pressure which could be produced by the tank booster pump would affect the temperature at which the delivery line became blocked.

In practice the designed delivery pressure of tank booster pumps varies from about 5 lb to 15 lb per square inch. The main programme of tests to investigate the occurrence of blockage in the delivery line from the pump had been conducted with a delivery pressure of 14·7 lb per square inch, and so further tests were made in which the

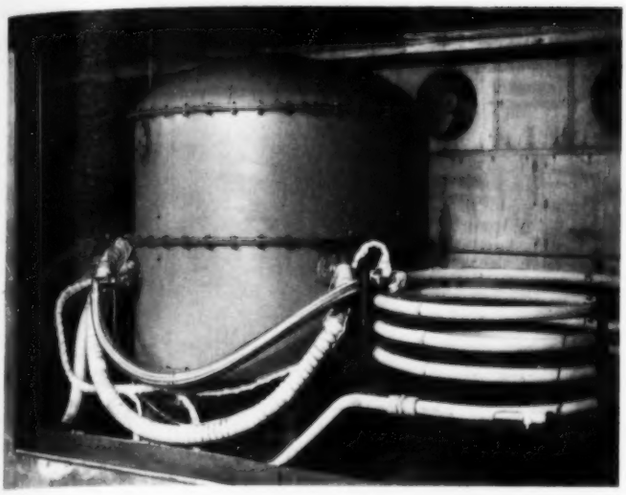
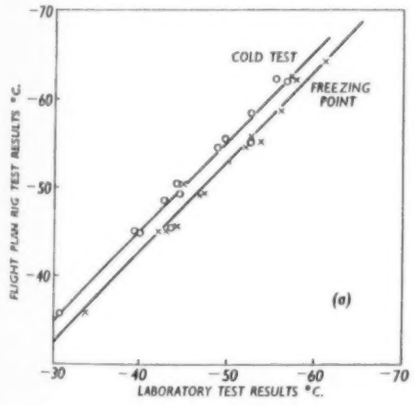


Fig. 5—Rig used for flight plan tests

pump was operated with a reduced supply voltage to cut the delivery pressure to 5 lb per square inch. The rate of flow was held at the original level by adjusting the control valves in the fuel line. Two kerosines were tested at the lower pressure and in both cases there was a small change in the results compared with those obtained with the higher delivery pressure. However, as indicated in Table I, the effect was only of the order of 1 deg. Cent.

As mentioned earlier, a 45ft delivery line was used in the main programme of tests, and to investigate the effect of a shorter pipe run three kerosines were tested in the rig with a delivery line only 13ft in length. Once more, a small effect was observed which showed, as expected, that the longer pipe run was more readily blocked than the shorter.

The results indicate that when the limiting temperature is approached a small drop in temperature induces a heavy precipitation of wax. Thus, if any change is made to the physical arrangement of the pipe, or to the pressure applied to the ATK, so that the tendency to block is reduced, a small temperature drop will stiffen the matrix sufficiently to cause blockage.



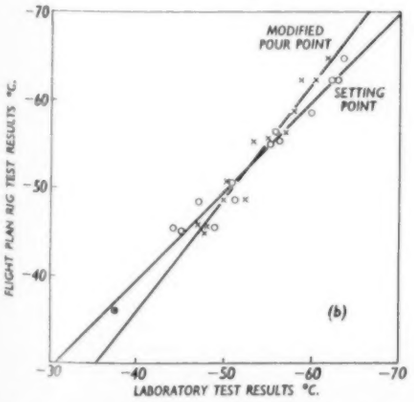


Fig. 6 (*a*) Fig. 6 (*b*)—Relationships between rig and laboratory test

Laboratory Tests

In the current edition (eighteenth) of the Institute of Petroleum Handbook *Standard Methods for Testing Petroleum and its Products*, three tests are given which relate to the performance of petroleum products at low temperatures. A fourth test was previously included but is now obsolete; and a further test is included in the American Society for Testing Materials handbook *ASTM Standards on Petroleum Products and Lubricants*. These five tests are as follows :

(i) Cloud Point—Serial Designation IP 15/55 Method A and ASTM D97–57. In this test the sample is cooled under prescribed conditions and is inspected at intervals of 2 deg. Fah. The temperature at which a cloud or haze appears is taken as the cloud point.

(ii) Pour Point—Serial Designation IP 15/55 Method B and ASTM D97–57. In this test the sample is cooled under prescribed conditions and is inspected at intervals of 5 deg. Fah. until it no longer moves when the plane of its surface is held vertical for five seconds. The pour point is then taken as 5 deg. Fah. above the temperature of cessation of flow.

(iii) Cold Test—Serial Designation IP 16/44 Tentative Method B. In this test the sample is dried and cooled under prescribed conditions, with stirring, until crystals of hydrocarbons appear. The sample is then allowed to warm up and the temperature at which the crystals disappear is noted.

This is the standard low temperature test in British aero gas turbine fuel specifications.

(iv) Setting Point—Serial Designation IP 54/42 (obsolete and not now included in the IP Handbook). In this test the sample is cooled under prescribed conditions in a tube, and at intervals a small pressure is applied to the sample. The setting point is taken as the temperature at which the material ceases to flow.

(v) Freezing Point—ASTM Designation D1477–57 tentative. In this test the sample is cooled under prescribed conditions, with stirring, and the temperature at which a "slurry of crystals" forms throughout the fuel is taken as the freezing point.

This is the standard low temperature test in U.S. aero gas turbine fuel specifications.

The fourteen ATKs which had been tested in the rig were all tested by the five procedures outlined above and, as might be expected, methods (i), (iii) and (v) gave results which were higher than those obtained in the rig. These laboratory methods all measure the temperature at which solid hydrocarbons begin to separate, whereas in the rig the temperature is measured at which sufficient material has been precipitated to form a matrix structure which will resist an applied pressure. There was not a constant difference between the rig results and the results from these laboratory tests, as will be seen from Fig. 6(a) so no "correction factor" could be applied to the latter in order to provide a reasonable estimate of performance in the rig.

The Pour Point and Setting Point tests both measure the temperature at which the liquid has set sufficiently to resist a small applied pressure. In the standard Pour Point test, the chilled sample is inspected every 5 deg. Fah. To improve accuracy, the procedure was modified by reducing the increments to 1 deg. Fah. and quoting the temperature at which the sample first ceased to flow.

The relationship between the rig tests with the long delivery line and both the Modified Pour Point and the Setting Point was particularly good and is shown in Fig. 6 (*b*). The results confirmed that those laboratory tests which more closely matched the conditions in the rig gave the best indication of performance. From this observation it appeared that, to obtain even better agreement, a laboratory test should be designed with the aim of matching very closely the rig conditions.

Such a laboratory test has been developed at the BP Research Centre and has been called tentatively the "Laboratory Pumpability Test." In this test a small sample (ca 10 millilitre) of the test kerosine is contained in a glass tube of specified dimensions

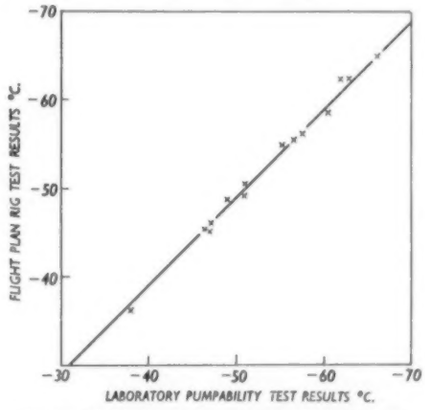


Fig. 7—Flight plan test compared with laboratory test pumpability

which is immersed in a cooling bath capable of producing temperatures down to −100 deg. Cent. The temperature of the bath is lowered at a prescribed rate and at intervals of 1 deg. Cent. a pressure of 2 centimetres of mercury is applied across the tube, the resultant flow of the fuel being shown by movement of a bubble in an indicator tube. Eventually a temperature is reached at which the sample does not flow when the pressure is applied and this temperature is recorded as the low temperature pumpability limit of the kerosine.

The results obtained using this test are plotted against the flight plan rig tests in Fig. 7 and it will be seen that the agreement is extremely good. The results available at

Technical Contributors Section (*continued*)

present indicate that the test gives results in such close agreement with the simulated flight plan tests that little further development of the apparatus or procedure is required. The test fulfils all the major requirements of a specification test, i.e. it is repeatable, gives results in very close agreement with tests made under simulated service conditions and consists of a relatively simple apparatus and procedure.

Effect of Adjustments of Low Temperature Performance on Production of ATK

If a kerosine is produced to meet a specified level in the ASTM Freezing Point test, or any other test of low temperature performance, the distillation range will automatically be limited. If the final boiling point is too high then the low temperature behaviour will be

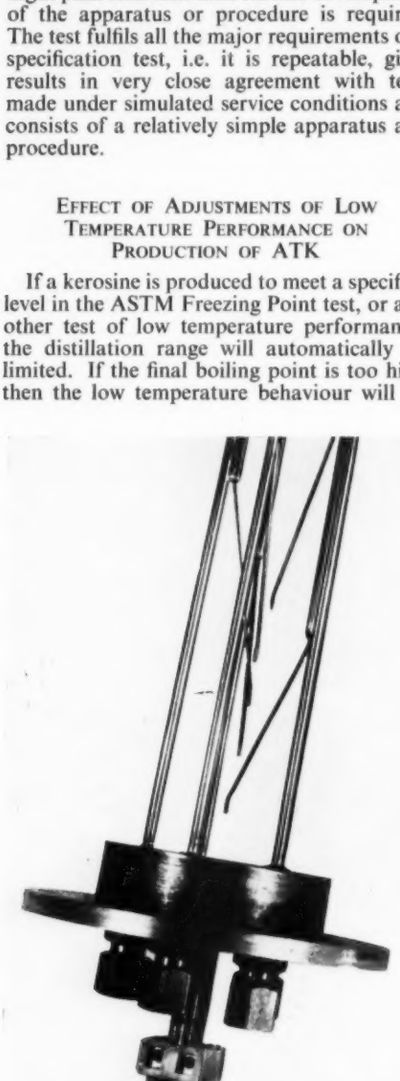


Fig. 8—Close up of probe for thickness measurements

poor. This may be alleviated by reducing the initial boiling point but the inclusion of light ends is restricted by a limitation on flash point which is incorporated in ATK specifications. In general if the final boiling point is reduced to improve the low temperature flow properties the initial boiling point has to be increased in order to maintain an acceptable flash point. Thus limitations on low temperature flow properties effectively limit both the front and back end cut points and hence the maximum yield obtainable on crude oil. The relationship between IP Cold Test values and the maximum yield of ATK from a typical Middle East crude (Kuwait) has been examined and the relevant figures are presented in Table II. The yields quoted are estimates of those obtainable under good refinery fractionation conditions and are based on yields which were obtained in carefully controlled pilot plant test runs. The effects of variation in ASTM Freezing Point can be adequately estimated by assuming the yields refer to test values 2 deg. Cent. below those quoted for the IP Cold Test.

In the particular investigation described the kerosines were produced to meet British Specification D. Eng. RD 2482, but they would also meet most of the clauses of ASTM specification "type A" which is a similar specification. The only major divergence is in the flash point which is set at 110 deg. Fah. minimum in the American specification and 100 deg. Fah. minimum in the British; the effect of this increase in flash point would be to reduce slightly all the yields quoted in Table II. Calorific values of the kerosines are presented in Table II and are of particular interest since with the −60 deg. Cent. Cold Test kerosine the level has fallen perilously close to the limit of 121,500 B.Th.U./USG minimum required for ASTM "type A" kerosine. Also it should be noted that as the Cold Test value is reduced the specific gravity approaches the lower limit of 0·775 in the ASTM specification.

It is apparent from this investigation that any unnecessary limitation on low temperature performance to allow for unrealistic flight temperatures or for poor correlation between specification tests and service performance carries a penalty of reduced yield from crude. Also increased difficulty would be experienced in meeting other specification points if kerosines with IP Cold Test values in the region of −55 deg. to −60 deg. Cent. were ever required.

Fig. 9—Solidified kerosine in the cooling tank

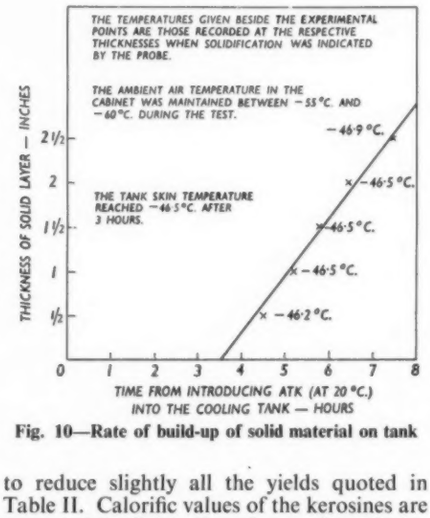


Fig. 10—Rate of build-up of solid material on tank

Build-Up of Solidified Material in the Fuel Tank

Aircraft manufacturers now appreciate the fact that exposed fuel lines are the most likely sources of blockage, provided that the filters are protected with heaters, and some aircraft are being designed to operate for most or all of the flight time with the fuel being drawn simultaneously from all tanks. There is much less tendency in these aircraft for blockage to occur in the fuel lines. If the fuel flows into the tank booster pump, any crystal structure which has formed will be broken up in the pump and it is unlikely that it will block pipes. The next weakest link in the fuel system is the fuel tank itself.

Many modern turbine-engined civil aircraft are fitted with integral tanks which allow good heat flow from the fuel in the tanks to the outside air. Thus at low ambient temperatures it would be possible for solidified material to build up on the tank walls and reduce the effective capacity of the tanks. The effects of build-up would be most serious towards the end of the flight, under conditions of low ambient temperatures, when the fuel adhering to the walls could form a significant proportion of the fuel remaining in the tanks.

An investigation has been made in the rig of build-up of solidified kerosine on the tank bottom. A test probe was designed to indicate when solidification had occurred at predetermined distances from the bottom of the tank. The probe, shown in Fig. 8, consists of a series of fine capillary tubes which terminate at intervals of ½in from the tank wall when the probe is in position. Arrangements are made for a small pressure to be applied to each tube at intervals. In

TABLE II

Kerosine	IP Cold Test deg. Cent.	Maximum yield of ATK percentage weight	SG	Cut points deg. Cent.	Flash point Abel deg. Fah.	Calorific value (net) B.Th.U./lb	Calorific value (net) B.Th.U/USG
A	−40	23	0·7975	125–289	103	18,695	124,300
B	−50	16	0·7895	132–251	105	18,985	125,000
C	−60	10	0·7805	138–220	104	18,690	121,600

test runs using this apparatus the rate of growth of the solid layer was measured by noting the time at which blockage was observed at each level.

In conjunction with this probe, a series of thermocouples was mounted in the tank bottom at the same radial distance from the tank wall and at the same distances from the tank bottom as the test probe elements. With both pieces of apparatus the objective was to measure the physical conditions of the ATK without introducing an alternative heat flow path, since this would have altered the rate of build-up of the solidified material. Also the test probe was designed to ensure that there would be no tendency for blockage to occur in the apparatus itself, except at the open end of the tubes.

Fig. 10 shows the results of preliminary test runs with this apparatus; it can be seen that the build-up progressed linearly with time. From simple considerations it would be concluded that the rate of build-up should fall off with time, due to the heat insulating effect of the layer already adhering to the tank wall. However, the bulk temperature of the kerosine falls at the same time as this layer increases in thickness, so that the quantity of heat required to be abstracted from the tank wall in order to maintain the rate of build-up is constantly decreasing. The results indicate that the conditions of test were such that the two opposing effects were approximately balanced, so that a constant rate of growth was produced after a time lag during which the tank wall temperature was reduced to the limiting temperature for the ATK under test. The temperatures indicated by the appropriate thermocouples when solidification was shown at each level by the probe ranged from −46·2 deg. to −46·9 deg. Cent.; this was in close agreement with the limiting temperatures of −47 deg. and −46 deg. Cent. obtained in the laboratory pumpability tests and the flight plan test respectively.

In these test runs the rate of growth of the "solidified" layer is not representative of expected rates of build-up in any particular aircraft fuel tank. With integral tanks, for example, heat transfer rates would be much greater because of the high air velocities over the tank surface. Also the rates of cooling will vary between tanks in service due to differences in materials, volume, surface area in contact with the fuel and cooled surface area. However, in the rig tests tank skin temperatures were measured, as well as fuel and air temperatures. It is reasonable to assume that tank skin temperature is equivalent to indicated air temperature and on this basis the temperature lapse rates of the fuel in the region of −40 deg. Cent. were comparable with those obtained in flight.

The photograph (Fig. 9) of the solidified kerosine in the tank was taken within two minutes of the cold chamber being opened. It will be seen that the solid material has detached itself from the tank wall; this was found to happen very quickly when the ambient temperature was raised.

Summary

Rig tests have shown that, even if ambient air conditions produce aircraft skin temperatures below the temperature at which ATK begins to solidify, failure of the fuel system can be delayed for some time. Aircraft manufacturers have already attended to one of the weakest links in the fuel system by fitting heaters to protect the fuel filters from blockage.

Fuel lines are vulnerable to blockage particularly if the ATK is stationary in them for an appreciable period of time at low temperatures. This feature is appreciated by aircraft manufacturers and the pumping pattern may well be adjusted in future so that in flight no exposed fuel pipes ever contain stationary kerosine.

If the foregoing precautions are taken the fuel tanks will probably become the part of the system most susceptible to the build-up of solidified ATK. This hazard is most likely to prove serious where integral wing tanks are used. The "solid" material, however, will detach itself from the tank wall if the tank surfaces are warmed, and it is reasonable to assume that floating solidified material in the fuel would be handled by the tank booster pump. Thus, if the aircrew are aware of the condition of the fuel and come down to a warmer level when solidification takes place, danger will be averted. Simple instrumentation such as that used in the rig to measure the rate of build-up of solid material in the tank might be of assistance to the aircrew in these circumstances. Preliminary tests in the rig indicate that the insulating effect of a layer of waxy materials adhering to the tank will not necessarily reduce the rate of build-up of that layer.

If unrealistic requirements for low temperature performance are incorporated in specifications for kerosine fuels for aircraft, increased production difficulties will result. The setting of unrealistic limits will be avoided if adequate service data are obtained and if specification tests are developed which are strongly correlated with service performance.

A laboratory test has been developed at the BP Research Centre for measuring the low temperature performance of ATK which gives results in good agreement with those obtained in a full scale rig operating under simulated flight conditions. This test has features which are desirable for an efficient specification test.

Acknowledgments.

The authors wish to thank the chairman and directors of the British Petroleum Company Ltd., for permission to publish this article.

A Design Criterion for Springs

By A. ORMEROD, B.Sc., D.I.C., A.M.I.Mech.E.*

THE standard formulae for calculating the stress set up in the usual types of spring by a given load and the deflection to be expected are well known. Although many graphs and nomograms have been constructed from these formulae to aid the designer, the non-specialist who is called on to design a spring for some specific purpose may find this wealth of information and the apparently large number of variables somewhat confusing. There would appear to be room for a re-assessment of the problem with the object of presenting the information available in a simple form which will indicate clearly the limits within which a designer may work. For example, in the early stages of a design it may be found desirable to use a compression spring which allows a movement of say ½in with a resistance building up from zero to 250 lb. It would be useful to know quickly whether an ordinary coil spring could be designed to give such a performance or whether a design to these figures would result in some rather unusual spring difficult to obtain or manufacture. The object of this article is to develop an expression to meet these requirements.

The Coiled Compression Spring

As a specific example it will be convenient to consider the familiar coiled spring in compression. These springs are made in a wide variety of shapes and sizes and it is, in fact, useful to consider separately shape and size. A particular spring is defined by three parameters, its shape, its size and the material of which it is made.

The Shape of a Spring.—In Fig. 1 the sketch defines the shape of the spring, but as no scale is given the spring may be of any size. The quantities which define the shape are seen to be : from the plan view, the ratio of the coil radius to the wire radius R/r, and from the elevation, the number of working coils N.

At first sight it may appear that the pitch of the coils should be specified, but the pitch will usually be fixed by the condition that at a given load the stress will reach its greatest permissible value, the desired deflection will be attained and the coils will close solid. Thus the pitch is not an independent variable and the shape of the spring is completely defined by the values of R/r and N.

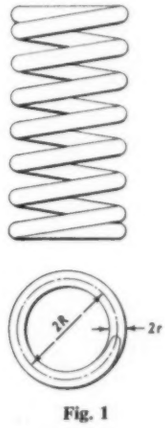


Fig. 1

A spring made up of a small number of turns of comparatively thick wire coiled to a small radius will be a stiff type, whilst a large number of turns of thin wire coiled to a large radius will constitute a flexible type of spring. The description of a spring as a "stiff type" or a "flexible type" is not directly related to its "rate" or "stiffness" measured in pounds per inch ; this quantity depends on the material and the size of the spring as well as on its shape. Thus a small stiff type of spring and a large flexible type may have the same rate.

The Strength of a Spring.—As the wire of the spring under load is practically in simple torsion, the spring is equivalent to the simple torsion bar shown in Fig. 2. The wire of radius r is subjected to a torque of WR and

* Royal Military College of Science.

Technical Contributors Section (*continued*)

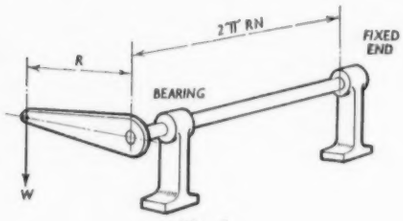


Fig. 2

if the working stress in the wire is q, the load W which can be carried is equal to

$$q\frac{\pi}{2}\frac{r^3}{R}.$$

This strength formula is arranged for future reference in the form :

$$r^2=\frac{W}{q}\cdot\frac{2}{\pi}\cdot\frac{R}{r} \quad . \quad . \quad . \quad . \quad (1)$$

The Deflection of the Spring.—Referring again to Fig. 2, it will be seen that the movement of the load is equal to the twist in the wire multiplied by R. If there are N coils the length of the wire is $2\pi RN$ and the deflection Δ is given by the relation :

$$\Delta=\frac{2\pi RN}{C}\cdot\frac{q}{r}\cdot R \quad . \quad . \quad (2)$$

where C is the shear modulus of the material.

The deflection formula may be written :

$$N=\frac{\Delta}{2\pi}\cdot\frac{C}{q}\Big/\left(\frac{R}{r}\right)^2 r \quad . \quad . \quad . \quad (3)$$

The Shape Formula

The formulae for strength and deflection may be combined in various ways, the most obvious combination W/Δ giving the spring rate. It has already been noticed that the rate is a very incomplete definition of a spring. Pursuing the principle that a spring may be defined by its material (C and q), its shape (R/r and N) and its size, it seems fruitful to seek a combination which will group the variables under these headings and the following form recommends itself :

$$\frac{W}{\Delta^2}=\frac{C^2}{8\pi q}\Big/\left(\frac{R}{r}\right)^5 N^2 \quad . \quad . \quad . \quad (4)$$

The term C^2/q indicates the effect of the material chosen for the spring, whilst the term $(R/r)^5\ N^2$ indicates the effect of the shape of the spring. It will be seen that if it is desired to design a spring for a given load and deflection the value of W/Δ^2 has great significance. A high value indicates that the spring must be of the stiff type (low R/r and N), a low value indicates a flexible type of spring (high R/r and N).

When the material has been chosen and the shape decided by fitting appropriate values of R/r and N to the formula (by a procedure to be developed later) the size of the spring can be found from the strength formula (1).

Limitations of Shape

Whilst it is difficult to define precisely the extreme values which individual designers or manufacturers would consider permissible for R/r and N, a range of variation which would include most " ordinary " springs can be roughly assessed. Thus for stiff types of spring as R/r is made smaller the simple formulae for strength and deflection cease to be accurate and correction factors have to be applied. Such springs may also be more troublesome to form, and it may be thought undesirable to make R/r less than, say five. For flexible types of spring, as R/r is made larger the pitch of the coils increases and some upper limit, say 15, may be thought appropriate. There are similar limitations on the number of coils to be used. If the number is small the uncertainties due to the effect of the end coils increase in importance. Although springs with very few coils (down to spring washers) can be used it may be thought that a minimum of five working coils is desirable. If too many coils are used the spring may be unstable in compression and need a guide to steady it, so an upper limit of say 15 may be chosen.

It is interesting to see the range of values W/Δ^2 may have within these limitations. Assuming that a steel is used with a value of C of 12×10^6 lb per square inch and a working stress of 10^5 lb per square inch, for a stiff type of spring with five coils and a value of R/r of 5, $W/\Delta^2=750$ lb per square inch approximately. For a flexible type of spring with fifteen coils and R/r value 15, $W/\Delta^2=\frac{1}{3}$ lb per square inch approximately. These values, of course, are not rigid ; if, for example, economic use of material is not important a still stiffer type of spring could be designed by working at a low stress. However, for values of W/Δ^2 which fall within this range a perfectly normal spring can be designed. Although the range seems wide the hypothetical spring mentioned in the introduction falls outside it.

The Design of a Spring

If a spring is to have specified values of load and deflection, the amount of energy to be absorbed is $\frac{1}{2}W\Delta$. A wire in torsion will absorb an amount of energy $q^2/4C$ per unit volume. The volume of metal required is then $2W\Delta.\ C/q^2$ and is thus dependent on the properties of the material selected. The material will be chosen after considering permissible weight and working conditions, for example a corrosive atmosphere may preclude the use of steel. Service conditions must be considered also when fixing the working stress ; a low working stress may be necessary to avoid fatigue failure.

When the material has been chosen the next step is to consider the shape. The desirable range of values for both R/r and N is roughly the same, i.e., 5 to 15. Advantage may be taken of this to introduce a great simplification at this stage. It it is tentatively assumed that $R/r=N$ the shape formula (4) which may be written,

$$\left(\frac{R}{r}\right)^5 N^2=\frac{\Delta^2}{W}\cdot\frac{C^2}{8\pi q} \quad . \quad . \quad . \quad (5)$$

reduces to :

$$\frac{R}{r}=N=\sqrt[7]{\frac{\Delta^2}{W}\cdot\frac{C^2}{8\pi q}} \quad . \quad . \quad (6)$$

If the value of R/r and N found in this way is close to the extremes, i.e. 5 on the one hand or 15 on the other then the design is " tight " and little variation is possible. If the value found falls well within the range then adjustments can readily be made to the shape of the spring to meet possible design restrictions on outside or inside diameter or on the free height.

The shape of the spring having been tentatively fixed, the size required is determined from the strength formula (1) which gives r and hence R. The overall dimensions will be, of course, outside diameter $2(R+r)$, inside diameter $2(R-r)$, free height $2rN+\Delta+$ an appropriate allowance for the inactive end coils.

A spring has now been found which will satisfy the required conditions, but it may be desired to modify the overall dimensions. This can be done by going back to the shape formula (5) and working through the design again. Suppose, for example, it is desired to decrease the outside diameter. This can be done within limits by reducing R/r and increasing N. This part of the work may be facilitated by constructing a simple chart as in Fig. 3 from which it can be seen, for

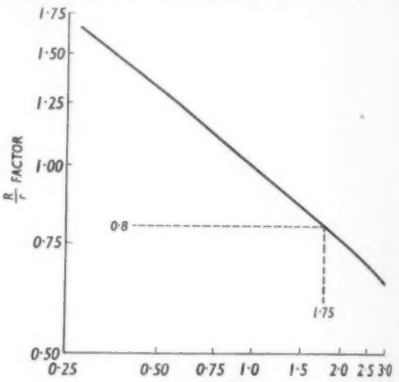


Fig. 3

example, that if R/r is changed by a factor of 0·8, N must be changed by a factor of 1·75.

In most cases final adjustment will be made to simplify manufacture by bringing r and R to " preferred " sizes. It will be unusual if all the desired conditions can be achieved without minor modifications to the values of W, Δ and q originally specified. A satisfactory compromise is reached by skill and judgment rather than by the application of fixed procedures, but should be possible by using the formulae already given.

Conclusion

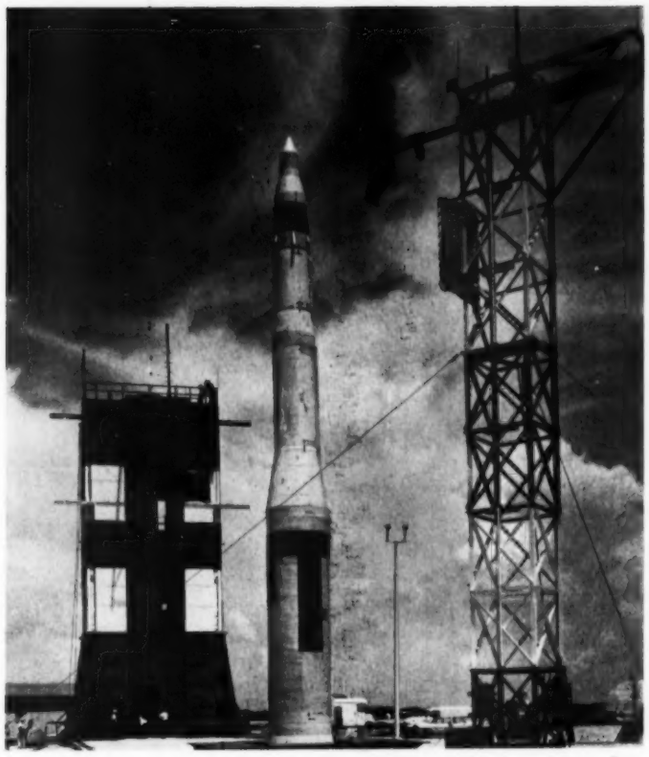
This appraisal of the characteristics of a spring suggests that the quantity W/Δ^2 has fundamental significance. The value of W/Δ^2 might be referred to as the shape index of the spring and classifies it as a stiff or flexible type. There are limitations to the range of value within which the shape index must lie. Although a coiled spring in compression has been used as a model for discussion the shape index has equal significance when applied to other types of spring.

Making use of the index, a simple and logical approach to the design of springs has been suggested.

Rockets and Space Flight, 1960

By JOHN E. ALLEN*

No. I



Progress during the first year of a new decade—which will be the first complete decade of space flight—is reviewed under the headings of rocket propulsion systems, rocket propelled vehicles (including satellites and space probes), and man-in-space. Future trends, as shown by such details as have been released, are indicated wherever possible.

A PREVIOUS article[1] reviewed progress in rockets and space flight up to 1960. The purpose of the present article is not to list and comment on the various long-term projects which have been mooted, but to review the solid achievements and current trends of activity of the year 1960, together with future projects officially announced during the year. There are two factors to be considered in applying a yardstick of progress: successful "firsts," and reliable repetition.

Both the Russians and the Americans have made notable advances in space flight, the Russians having gone all out for bigger and more powerful boosters with good weight-lifting capability, and followed up their "Pacific" rocket test flights with three orbiting vehicles which have been described as "dummy spaceships" in preparation for manned orbital flight, and the Americans having achieved quite a variety of impressive "firsts" such as the "Echo" passive communications, "Tiros" meteorological, and "Transit" navigational satellites, and the "Pioneer 5" artificial planet. A specially notable feature of the American programme has been their success, repeated several times, with the "Discoverer" satellites—the reward of long and patient perseverance. Without data on Russian failures, on which they remain reticent, one cannot compare East and West with regard to reliability. The American vehicles incorporate their advances in the miniaturisation of instruments and electronics, and in production methods employing newly available materials such as beryllium and molybdenum. Also, in spreading their endeavour over such a wide range of experiments they have demonstrated the feasibility of several major applications of spaceflight, and gathered vast quantities of new and useful data on the space environment. It should be remembered that "Vanguard 1"—the "grapefruit" satellite—is still in orbit and is still transmitting. On balance, although the Americans do not at present have a booster of similar power to that used by the Russians to launch their 10,000 lb. class "Sputniks" 4, 5 and 6, activity and progress in the U.S.A. during 1960 have been more marked than in the U.S.S.R. The highlights of progress will be reviewed under "Rocket Propulsion Systems," "Rocket Propelled Vehicles," and "Man in Space."

ROCKET PROPULSION SYSTEMS

The Science and Astronautics Committee of the American House of Representatives have asked industry to help them in reviewing present and future propulsion programmes. Representatives of industry, together with the N.A.S.A. and the American forces, have been asked to consider various fields. One of these is the need for development of a family of space boosters not connected with I.C.B.M. vehicles, although N.A.S.A. have already planned such a family and are well under way with one of its major members, namely "Saturn." Others are the use of atomic energy in space boosters; the use of various combinations of liquid, solid and atomic stages; the relationship between booster reliability and simplicity, overall cost and overall success; and the feasibility of recovering, and using again, boosters for manned space vehicles. Probably the most significant, however, is their request for a study of solids versus liquids for large space boosters, for during the year the swing towards solids has become even more marked.

Solids versus Liquids

In addition to the advantage of instant readiness, which it seems the solids will always have over liquids, the outstanding progress made with "Minuteman" and "Polaris" has revealed some very sound logistic advantages. The higher specific impulse and cheapness of liquid propellants themselves were shown to be of less importance than overall cost of the system, reliability, and simplicity of operation. Solids are easier to store and handle, and require fewer men and therefore smaller establishments than liquids. Much greater mobility, as well as significant reductions in overall cost, have resulted. For some time, no new major weapons employing liquids have been envisaged by the Americans. Existing liquid systems are being modified to use "storable," hypergolic combinations, or are having cryogenics replaced by combinations more easily handled in the field. In space propulsion, where mobility and instant readiness are not major factors, solids cannot compete at present with liquids, one very practical reason for this being that large liquid boosters are already in advanced stages of development, such as the "Saturn" engine. Theoretically, however, solids could be profitably used in space boosters for the following reasons:

(1) They allow a greater thrust-to-weight ratio, and therefore give greater acceleration from ground level to altitude, thus permitting some performance advantages.

(2) They have virtually no moving parts and therefore greater inherent reliability and simplicity. In all tests of "Minuteman" and "Polaris" to date, for example, there have been virtually no failures attributable to the propulsion systems.

(3) Overall cheapness, for the reasons already given—but technical arguments on the relative costs of solids and liquids which went on during 1960 are likely to be continued for some years to come.

(4) Since the trend is towards recoverable boosters, these will have to be of rigid construction. Most of the large liquid systems, with the notable exception of "Saturn," are incorporated into very thin airframes some of which have to be pressurised in order to withstand launch.[2] Liquid propellant tanks can also be made very thin and light, since it is only the combustion chamber and nozzle which have to withstand considerable stresses and high temperatures. With solids designed for low altitude launch and therefore with high combustion pressures, the whole case must anyway be strong and rigid. If liquid propellants were used in a recoverable booster, some of their specific impulse

* Member, American Rocket Society; Member of Council, British Interplanetary Society.

Fig. 1—Checking for deterioration in Grand Central's large solid propellant mixer. These technicians are inspecting the stainless steel blades

advantage *vis-a-vis* solids would be counterbalanced by the increased weight of rigid construction. It would also be much easier to clean and refill solid boosters with propellant.

In liquids for space purposes the emphasis in the U.S.A. is on liquid oxygen and kerosene for the " Saturn " cluster and for the single-chamber 1·5 million lb thrust " Nova " F-1 engine, and the liquid oxygen and liquid hydrogen 200,000 lb thrust engine for " Saturn " upper stages. Liquids are even losing a certain amount of their former advantage in respect of stop/start and throttling capability since the recent successful tests of hybrid solid/liquid systems, but complete controllability has not yet been achieved with solids alone. For upper stages needed for precision manoeuvres, for example, into orbit or to a landing on the moon, liquids are still preferred. In specific impulse, they are likely to remain ahead, although the present margin may become smaller.

Solids

There are two basic reasons for current interest in large solids, which may clarify what has already been said above.

Firstly, the traditional concepts of staging are based on the belief that each stage should increase the payload velocity by an equal amount. Optimum staging ratios have been studied by the Grand Central Rocket Company and by N.A.S.A.: these studies show that present staged rockets with the traditional " pyramid " concept are not taking advantage of the increased efficiency of rocket engines at high altitude. According to the N.A.S.A., the proper optimisation of staging ratios in large solid rockets should make it possible to put 1 lb of payload into orbit for every 50 lb of propellant, instead of for every 800 lb of propellant as at present.[3] Liquid upper stages, and especially liquid hydrogen–liquid oxygen systems, will be used for the highest power and precision manoeuvres. It should be remembered here, however, that solids may also be used with advantage in space, where good specific impulse values can be obtained at lower combustion chamber pressures : solid motors can be designed for operation at very low chamber pressures, and can therefore use lightweight cases to obtain very high mass fractions (proportion of total weight which is propellant). An example is provided by " Altair," the small 3070 lb thrust solid rocket, which was used to apply the last impetus to " Pioneer 5," " Tiros 1," and others. " Altair," produced by the Hercules Powder Company, has a mass fraction of 0·92, and the mass fraction of a hen's egg is only 0·89. A lightweight case of " Spiralloy "—glass fibre wound in filaments and reinforced with epoxy resin—is loaded with 465 lb of double-base propellant.[4] A new high mass ratio solid motor of revolutionary design is under development by Grand Central for N.A.S.A., but no details have been released.

Secondly, in order to meet the need to get the vehicle to high altitudes as efficiently as possible, solids are theoretically more efficient than liquids because they can readily develop higher thrust-to-weight ratios during rapid burning, thus losing less impetus due to gravity than the comparatively slow-burning liquids.[5]

With the success of the relatively small " Polaris " and " Minuteman " solid rocket missiles, the N.A.S.A. have now embarked on active support for very large solid rockets for space boosters, and have awarded contracts to Aerojet-General Corporation, Grand Central Rocket Company and Thiokol Chemical Corporation, for the preliminary design of solid boosters of up to 7,000,000 lb weight and capable of clustering for thrusts up to about 20,000,000 lb; and such boosters would probably be used in vehicles of the " Saturn " and " Nova " class together with liquid hydrogen–liquid oxygen upper stages.

Aerojet-General also have a contract from the U.S.A.F., under their Project 3059, for a large solid with well over 1,000,000 lb thrust. This would be about two-thirds the size of the present liquid " Saturn " booster. The first static firing is due in 1961, and if later proved successful it could compete with " Titan " as " Dyna-Soar " booster. Since " Dyna-Soar " is a military vehicle, the U.S.A.F. are particularly interested in the instant readiness advantage of solids. Aerojet-General and Grand Central Rocket Company are using segmented construction for their large solids.

Boosters of this size, which may be up to 24ft diameter and about 160ft in length, could not possibly be transported in one piece by road or rail to a launching site, and segmented construction at the factory is thought to be one solution. Thiokol have been reported as in favour of on-site mixing and loading of the propellant, but mobility advantages would be lost, and some attention would have to be given to on-site quality control—difficult enough in the factory—and to the problem of disposal or destruction of the huge solid motor in the event of deterioration. In segmented construction, the propellant is cast into cylindrical casing segments of convenient length. Grand Central propose to tackle the problem of controlling burning at the surfaces between segments by abandoning the customary asterisk section charge ports in favour of circular section charge ports with wedge-

Fig. 2—Test firing of a first stage engine for the " Titan " I

shaped gaps at the segment interfaces.[5] Extra heat insulation is needed at the casing joints, which may also be structurally reinforced by means of bars.

There is another branch of segmented solids development. United Technology Corporation (a division of the United Aircraft Corporation) have a N.A.S.A. contract for demonstrating the feasibility of conical-shaped segmented solids, and fabrication is being done by the Pratt and Whitney Division. In this concept, the aim is not merely to avoid transport, handling and other difficulties, but to continue the general trend towards modular construction in rocket technology. The segments are conical with the small end uppermost, and this configuration is claimed to increase the flow area as the charge length is increased, thus allowing quite large increases in length without erosive burning. The avoidance of erosive burning leads to better prediction of ballistic performance. Since the short sections are open at both ends, inspection is also made easier.

The performance desired of very large solid boosters is the ability to place up to 50 tons of payload in orbit. This capability would make it practicable to place a vehicle larger than the currently projected " Dyna-Soar " in orbit. (The suggestion has also been made that whole groups of I.C.B.M. warheads could be launched at once !)

The great drive for higher-energy solid propellants was reviewed in a previous article[1] and there is little to add to this, for although much activity and improvement has been reported from several American companies —notably Thiokol Chemical Corporation,[6] Rocketdyne Division of North American Aviation, [7] United Technology Corporation,[8] and Grand Central Rocket Company[9] —such technical details as have been released are not sufficiently illuminating to permit a reliable assessment of the present state of the art. The Rocket Power/Talco Research Centre in California is carrying out experiments with fluorocarbon solids, which they believe will eventually give considerably better performance than present solids.

Britain and France are known to be active in the field of solid propulsion. Development in the United Kingdom is carried on mainly at the Rocket Propulsion Establishment, Westcott, and the I.C.I. Research Station at Summerfield. The largest British motor so far reported is the " Raven," used for the " Skylark " upper-atmosphere sounding rocket. The " Raven " delivers a thrust of 12,000 lb for thirty seconds, using 2200 lb of a British plastic propellant.[9] Some details of I.C.I. work were only recently revealed, namely at a Rocket Propulsion Symposium held at Cranfield during January 6–7, 1961, where two papers were given by I.C.I. representatives. The paper by J. M. Carter entitled " Thrust-axis control in solid propellant motors " described work on various types of thrust control in nozzles, including vane interference and swivel nozzles. The second paper was by H. M. Darwell, on " Solid-propellant dual thrust motors," describing experimental motors and revealing a surprising number of possible designs. (See THE ENGINEER, January 20, 1961, Page 91). The largest solid rocket known to be possessed by France is the " Veronique," used for upper atmosphere research. French activity in solid rockets and missiles has continued during 1960, with the follow-up intention of producing a second stage for " Blue Streak " if this becomes a space booster, but no details have been released.

The aim in U.S.A.F.'s " Midgetman" project is to produce a smaller version of the " Minuteman " I.C.B.M. for truck launching, and to do this by increasing performance with new grain designs rather than new propellants. The U.S.A.F. is said to have tested a multi-grain solid motor which could make " Minuteman " 37 per cent shorter and 24 per cent lighter.[10] The design, which has been called " Muroc," employs several stages with much more propellant loading space than in present designs. The multi-grained propellant is entirely volumetrically loaded and is capable of simultaneous burn-out at all points of the casing.[11]

The escape rocket for the Project " Mercury " manned satellite is being produced to the most stringent reliability specifications ever laid down by N.A.S.A., namely 99·9 per cent, and this rocket may in a sense be taken as a measure of the progress of reliability in solids. Grand Central Rocket Company are using conventional polysulphide-ammonium perchlorate propellant with aluminium additive, for there have been no failures with this combination to date. The specific impulse, however, is only about 205 lb seconds per lb, and the use of an extra-strong steel case reduces some of the rocket's efficiency. One of the tests required is the regular inspection of the internal surface of the grain, and consideration has been given to the periodic removal of $^1/_{32}$in of propellant from the surface to eliminate the danger of delay in ignition due to propellant deterioration. Quick ignition requirements have also resulted in the specification by N.A.S.A. of a very large igniter, and it is possible that one of Grand Central's newly developed group of sheet igniters may be used.

Reliability is not a function of size, according to the Aerojet-General Corporation, whose assessment of field operations with 100,000 solid rockets varying from 35,000 lb to 115,000 lb thrust showed a reliability of 99·96 per cent. It is worth noting that during 1960 " Polaris " has reached the operational stage, " Minuteman " tests were so successful that the test series budget was halved, all initial flight tests of " Pershing " have been successful, " Nike–Zeus " has shown similar promise in numerous tests, and " Skybolt " development has been commenced.

The Stanford Research Institute is doing considerable basic research on the reliability of solid propellants after storage. Such propellants can at present only be considered reliable for periods up to five years, with a possibility of fair reliability up to ten years. These studies affect logistic problems of such missiles as " Polaris," " Minuteman," " Pershing " and " Skybolt." The causes of deterioration are chemical interchange, temperature and humidity, or oxidisation, and these may be manifested in grain cracking, loss of shape at the points of asterisk-section charge ports, creep, or degradation of the polymeric binder. The results may be poor ignition, unstable combustion or even explosion. Methods of preventing or at least delaying deterioration are being considered such as the spray-coating of the grain surface with a protective sealant, enclosing motors in plastic envelopes with dessicants, or bulk storage in a special atmosphere.

The selective replacement of stored motors would be far cheaper than total replacement after fixed storage periods, provided the condition of the propellant can be determined by non-destructive methods, and one problem here has been the lack of a suitable instrument. An ultrasonic device has now been developed by the Stanford Research Institute to measure the energy absorbed by the propellant under test. By comparing the results with the characteristics of fresh propellant, it should be possible to judge whether more detailed inspection or replacement is necessary. This method may give more general indications than conventional X-ray procedures, which only reveal the presence of cracks or other discontinuities in the grain, and should in any event be cheaper than X-ray. Aerojet-General Corporation have developed a new radiation testing device which uses a slug of cobalt 60 as a gamma ray emitter to scan the internal surface of the grain. Detectors positioned outside the casing are said to be capable of revealing flaws as small as 0·03in diameter.

The U.S. Navy's Project " Hydra " envisages launching large solid rockets from the sea. Rockets would be floated in a vertical position prior to launch, the nozzle being sealed at atmospheric pressure by a diaphragm which is ruptured upon ignition. Promising small-scale tests of " Hydra 1 " were made at the Pacific Missile Range during the year. This method has applications to liquid and other rockets also, and offers particular advantages with future nuclear first stages.

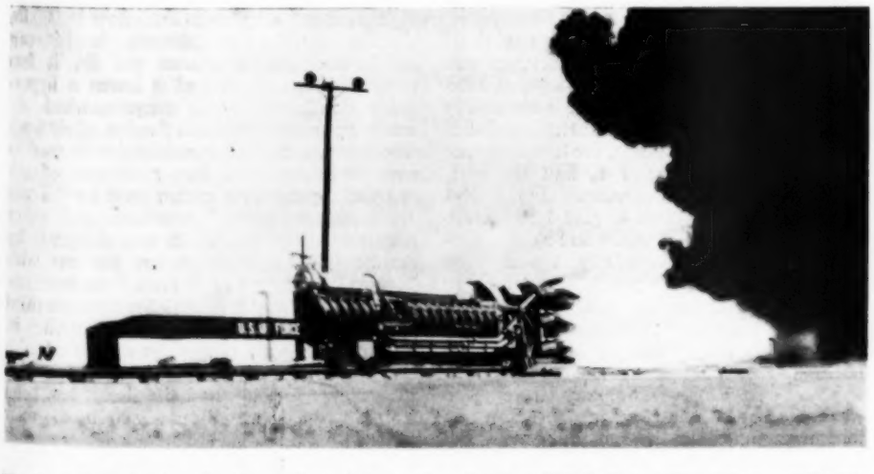


Fig. 3—A three-chamber, liquid-propellant engine, with a thrust of 114,000 lb in action testing a " Minuteman " guidance system at Holloman A.F.B.

HYBRIDS

One of the greatest advantages held solely by liquids has been that of stop/start and variable thrust. Various means of improving the versatility of solids with new charge designs, and by quenching combustion at the desired moment by injecting water have been developed as reported in Reference 1. The hybrid system, using a hypergolic combination of solid propellant and liquid

oxidiser, although not a new idea, has recently been developed practically. At the American Rocket Society's semi-annual meeting early in 1960, Grand Central Rocket Company reported tests made with a hybrid motor of 1000 lb thrust.[12] Complete throttling control was obtained over the entire thrust range, and stop and re-start capability was demonstrated by allowing periods of days between stopping and re-starting. The fuel was carboxylated-butadiene acrylonitrile with aluminium additive, and the liquid oxidiser was chlorine trifluoride. In hybrids, when the oxidiser is injected the mixture ignites hypergolically along the fuel surface, and combustion remains stable in spite of a constantly increasing burning area. The combustion chamber, however, has to be sufficiently long to ensure complete combustion of the oxidiser, and the fuel surface geometry is also critical. Aerojet-General Corporation were also doing private research in this field during 1959, and they now have a U.S. Navy contract to develop a hybrid engine.

Liquids

In missiles, the swing towards storables such as nitrogen tetroxide-hydrazine continues, and " Titan 2 " I.C.B.M. will use this combination. For space vehicles, the development of high-energy liquid oxygen-liquid hydrogen systems is continuing rapidly —the Pratt and Whitney LR-115 having been run for a record time of 5½ minutes— the H-1 liquid oxygen-kerosene engine cluster for " Saturn " has been made even more reliable, and the F-1 " Nova " single-chamber engine designed for 1,500,000 lb thrust has been successfully tested at above the 1,000,000 lb level. The ability to start liquid rockets at high altitudes has been demonstrated with the " Agena " upper stage and the " Titan " second stage. A liquid rocket was also shut down and re-started in space for the first time when the " Able-Star " put the " Transit 1B " navigation satellite into orbit on April 13. The X-15 rocket aircraft has been flown in tests of the stop and re-start capability of its new XLR-99-RM-1 engine, but over the much wider degree of control required for manned systems. Further progress has been made with fluorine systems, and there is renewed interest in pentaborane.

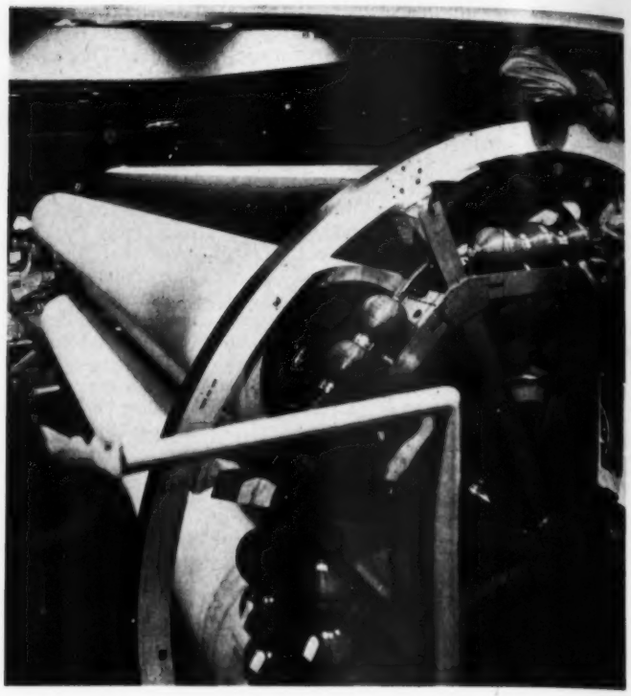


Fig. 5 — " Saturn " first stage, showing some of the eight " Jupiter " tanks used for liquid oxygen

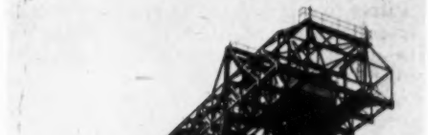


Fig. 4—177ft. static test stand at Marshall Space Flight Research Centre, Huntsville, Alabama, accepting a 1,500,000 lb thrust " Saturn " booster

Rocketdyne are developing for the N.A.S.A a liquid hydrogen engine of 200,000 lb thrust. Development may take up to three years, with an approximate cost of 44,000,000 dollars. Only single-start capability will be required at first, but the engine will probably be capable of modification for stop/start at some later date. The engine will be used in clusters of two or four for late versions of " Saturn " upper stages towards the end of the 1960's, thus increasing the payload capabilities of the initial " Saturn " vehicle, which are 25,000 lb into 300-mile orbit or 9000 lb sent out into space, by as much as 100 per cent if a cluster of four is used.[13] This is another large addition to Rocketdyne's already extensive responsibilities in the liquid field.

The F-1 single-chamber rocket engine of 1,500,000 lb thrust, which Rocketdyne are developing for "Nova" for use between 1963 and 1965, has been reported successfully tested at over 1,000,000 lb thrust, and full tests are planned for Spring, 1961, at Edwards Air Force Base. The F-1, like the H-1, uses liquid oxygen-kerosene. Eight H-1 engines will be clustered to give 1,500,000 lb thrust for " Saturn " (Figs. 4 and 5). Rocketdyne have also successfully tested their " Nomad " fluorine engine for upper stages ; this is in the 15,000 lb thrust class, with a pressure-fed system.[14] Liquid hydrogen is used for " Nomad," but hydrazine can also be used.

Bell Aerosystems Company have been working under contract to N.A.S.A. on fluorine systems for the last four years, and have tried hydrogen, ammonia and hydrazine as fuels. They have recently prepared a proposal to the U.S.A.F. for a liquid fluorine-hydrazine engine of about 15,000 lb thrust, with a turbopump feed system. Owing to the high bulk specific gravity of the propellant mixture, this combination offers a 50 per cent increase in performance compared with liquid oxygen-liquid hydrogen, and is also hypergolic. The engine is suggested for use in upper stages of advanced space vehicles. The " Centaur " vehicle is at present scheduled to use liquid oxygen–liquid hydrogen engines of about the same size. One of the worst problems in developing a fluorine engine with a turbopump feed system has been the sealing of the fluorine pump.

Pentaborane has received renewed attention, and the Callery Chemical Company have established a plant for production of this chemical at Muskogee, Oklahoma. The use of hydrazine as an oxidiser offers interesting possibilities; the reaction produces boron nitride and liberates hydrogen, giving a very low average molecular weight of the exhaust gases. The estimated specific impulse is 329 lb seconds per lb, much higher than nitrogen tetroxide and pentaborane at 296.[15]

The " Agena B " vehicle, now well established with " Thor " as the mainstay of the " Discoverer " programme, uses a modified Bell " Hustler " missile engine. Bell Aerosystems Company spent three years in modifying the engine, and the thrust is now 16,000 lb, specific impulse at altitude is between 290 lb and 300 lb second per lb, it has stop/start capability, and it burns a hypergolic combination of unsymmetrical dimethyl hydrazine and red fuming nitric acid. The same propellant combination is used in the " Able-Star," a larger version of the " Able " upper stage rocket used for " Transit " and " Courier " satellites and other programmes (Fig. 7). It was designed by Aerojet-General Corporation for use with " Atlas," " Thor " or " Titan " as boosters. The stop and re-start capability makes a third stage unnecessary for placing a satellite in a 300 to 600 mile orbit. As compared with the original " Able " there is over twice the propellant capacity, and the thrust has been brought up from about 7800 lb to over 8000 lb.

News has been released in the United Kingdom that the Bristol Siddeley " Stentor " rocket engine for the Avro " Blue Steel "

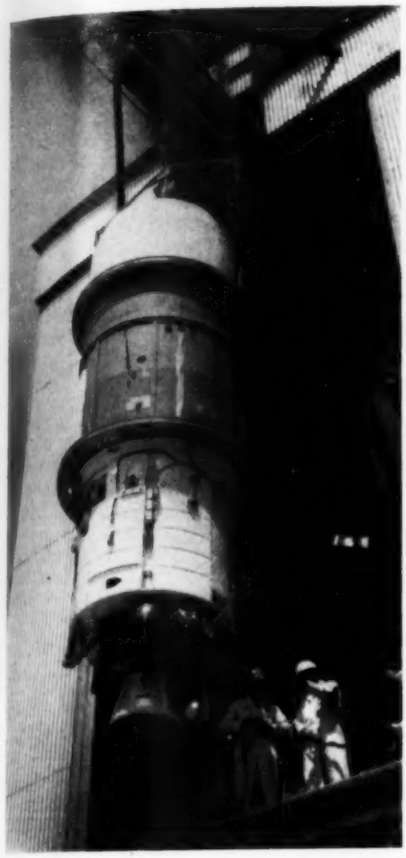


Fig. 6—Lockheed "Agena." A vehicle with a Bell "Hustler" engine for use in the "Samos" observation satellite programme

stand-off bomb, burning H.T.P. and kerosene, will be used to power production versions (Fig. 8). Performance details are not available, but it is generally assumed that the thrust is greater than the total thrust of the "Double Spectre," namely 16,000 lb.[16]

The clustering of liquid engines to form multiple units brings problems of its own. Basically, it is an expedient to obtain the desired total thrust reliably without undergoing extensive development delays, which are inevitable with large single units designed specifically for the desired thrust value. Calculations show,[17] however, that the component engines of a cluster must each be more reliable than a large single unit. J. E. P. Dunning, Director of the Rocket Propulsion Establishment, expressed the view during a Royal Aeronautical Society lecture on April 7, 1960, that reliability is a function of development, and that the smaller the unit the greater is the development it can receive. Hence a cluster may well be much more reliable than a large individual engine. He suggested the best size for a liquid rocket is around 50,000 lb thrust, larger thrusts being provided by clustering, but gave 250,000 lb thrust as an approximate upper limit—a cluster of four of these would weigh less than one unit of 1,000,000 lb thrust. Feasible cluster numbers were given as four up to nine.

Rocketdyne discovered some complications during the first firing of the 1,500,000 lb thrust "Saturn" cluster, for the eight H-1 engines are all coupled via the propellant tanks, making it possible for a sudden instability in one engine to cause instability in one or more other engines.[18] Before use in the cluster, each H-1 engine had a proved reliability of 96·5 per cent, following a development programme of 830 firings and over 100 hours' total running. The "Saturn" cluster allows in effect one spare engine, so that if any single engine fails in flight the booster will still carry out its purpose. Allowing this spare, the cluster reliability is 97 per cent. Without the spare, the multiple unit would have only a 75 per cent reliability for any given flight. Attention has also been given to the need for detecting unstable combustion in order to shut down the faulty motor before explosion occurs, and feeding the engines as independent units (i.e., with their own pumps, &c.) from common tankage to ensure that all propellant will still be consumed if one engine is shut down. Each engine develops 190,000 lb thrust, burning liquid oxygen and kerosene.

Some further improvements have been effected in the "Saturn" H-1, which had already undergone extensive simplification and modification for greater reliability, as reported in Reference 1. Full thrust now builds up automatically after one starting signal, whereas the previous version required an elaborate switching operation.[19] Following up their work of reducing the complexity of liquid engines, Rocketdyne have devised a system for tapping off combustion chamber products to drive the turbine, thus eliminating a separate gas generator to power the turbopumps and increasing reliability by reducing potential problem areas.[20] The performance is comparable to that of a conventional engine, starting being accomplished with a solid propellant turbine starter, but the tap-off or bleed system has only been proved with one type of engine, and more work has still to be done on other types. The number of functions performed, as compared with a conventional bi-propellant gas generator, is reduced from seven to two with the tap-off system. If the system is shown suitable for wider application, the following can be added to Rocketdyne's remarkable success in reducing numbers of components :

	Gas generator system	Tap-off system	Saving, with better reliability
Components	11	6	5
Static seals	11	3	8
Dynamic seals...	3	0	3
Total	25	9	16

Another Rocketdyne development was reported by G. V. R. Rao at the American Rocket Society semi-annual meeting in Los Angeles early in the year. This is an extension of the "plug nozzle" concept already reported.[1] The new configuration is of inverted mushroom shape and of lightweight construction. Called an "expansion-deflection" or simply "E-D" nozzle, it offers several new advantages such as the possibility of thrust vector control by tilting the mushroom button, or thrust modulation by fore-and-aft movement of the whole plug. High efficiency at low as well as high altitudes is claimed, owing to the automatic adjustment of the exhaust and its cross-section according to ambient pressure. The shortness of the nozzle should allow structural savings in staged vehicles.

The Reaction Motors Division of Thiokol Chemical Corporation have also made progress during the development of the XLR 99-RM-1, the engine for the X-15 rocket aircraft. Changes include the reduction of the number of components where possible. The new XLR 99-RM-1 engine for X-15 is required to start, operate, be capable of idling, stop and re-start, in all environments including space. It must also have the fine degree of control necessary for pilot operations.

The first X-15 was powered by two XLR-11 engines giving a total sea-level thrust of 16,000 lb. The XLR 99-RM-1 engine has been shown on test to have a reliability better than 98 per cent, and has performed in temperatures of −65 deg. Fah. to +165 deg. Fah. and also at 300 deg. Fah. The specific impulse is 284 lb seconds per lb, the thrust is 50,000 lb at sea-level and 58,500 lb in vacuum, and the size is 41in by 72in. The importance of this engine, which burns liquid oxygen and anhydrous ammonia in its present version, may be summarised as follows :

It is the only rocket engine of this size designed with full stop/start and throttling capability for pilot use ;

Adaptability to higher energy propellants, being capable of thrusts up to about 100,000 lb without major changes ;

Versatility—possible use for "Dyna-Soar" or manned lunar landing.

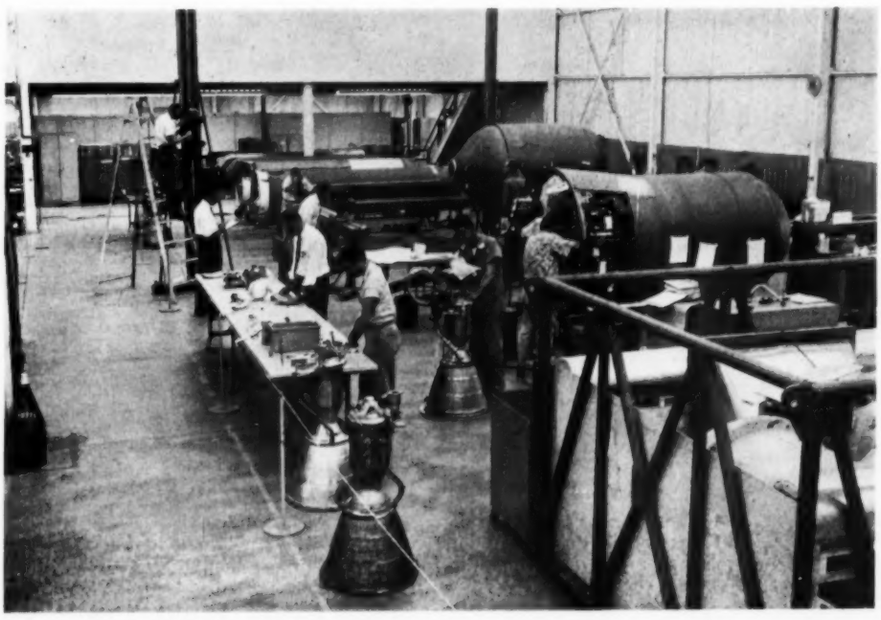


Fig. 7—"Able Star" power units being assembled at Azusa ; notice the use of surveying techniques to obtain accurate alignment

Electric

At least two state-of-the-art surveys have appeared fairly recently,[21, 22] and there have also been shorter reviews.[23, 24] The purpose of this section will therefore be to note some highlights of the year.

The terminology is slowly becoming more standardised. Three groupings are made, as follows :

Electrothermal—now described as "arc-jet" (previously referred to as plasma or plasma-arc). These are the systems in which a propellant gas is heated by passage through an electric arc and ejected through a nozzle. They differ from chemical systems in the use of an electric arc, rather than chemical reaction, to heat the propellant gas.

Electrostatic—"ion," in which charged particles (ions) are accelerated by causing them to fall through a drop in potential, thrust being caused by the interaction of lines of electrostatic force with electrodes fixed in the engine. In order to prevent the ion beam from merely building up a positive charge outside the nozzle and preventing further ions from leaving, electrons sufficient to neutralise the ion charge must also be ejected, and in this lies a main research and development problem.

Electromagnetic—"plasma" or "plasma-pinch" (still may be found described as "magnetohydrodynamic," "magnetogas-dynamic," or "magnetofluid-dynamic" propulsion), in which the awkward problem of beam neutralisation does not arise, for the propellant gas—though in a plasma state and hence largely ionised—forms an externally neutral plasma, and its positive and negative particles are not separately accelerated. In plasma systems, acceleration is achieved by the action of a magnetic field upon a current through the plasma, thrust resulting from the interaction of magnetic fields. Experiments are being made with both continuous and pulsed versions, but there are many problems still unsolved.

Arc-jet and ion systems are approaching the stage when practical experiments will be conducted in space. In the case of ion engines, this is highly desirable and a matter of some urgency, since it will not be known for certain whether it is practicable to neutralise the ion beam effectively until flight tests have been made. During the first half of the year. N.A.S.A. held arc-jet and ion competitions from which several contracts resulted.

One of N.A.S.A.'s requirements was a 0·5 lb thrust arc-jet for use with 30kW or 60kW SNAP-8 power units for interplanetary probes. The A.V.C.O. Corporation have such an engine under development, and have run it continuously for about fifty hours.[25] Like all electric propulsion systems, it could only be used from a vehicle already established in space. The thrust is about 0·5 lb, with a specific impulse of between 750 lb and 1500 lb seconds per lb. Hydrogen or helium may be used. Another requirement was an arc-jet of 0·01 lb thrust for use with the 3kW "Sunflower" solar power system, possibly for attitude control and orbital correction for satellites.

An ion engine of about 0·01 lb thrust is also needed for use with the SNAP-8 nuclear-electric supply. This would probably be clustered in a group of ten engines initially, and later scaled up to 0·1 lb thrust. A contract for a motor of this type was awarded to the Hughes Aircraft Company in June. Electro-Optical Systems Incorporated have a contract from Wright Air Development Centre for rapid construction of an ion unit, and this would facilitate early flight testing. In one of the Electro-Optical Systems designs, as many as nineteen ion beams are obtained from a single motor by using hexagonal arrays of porous tungsten ionising surfaces.[26] The U.S.S.R. is also believed to have made progress in ion systems,[27] but no up-to-date details are available.

A remarkable number of American companies is interested, and therefore presumably equipped for research, in electric systems. As many as sixteen companies, for example, competed for the N.A.S.A. arc-jet and ion contracts already mentioned. Experimental ion systems have been operated at exhaust velocities of 130,000 to 195,000ft per second, with caesium as the ion source.[25] Specific impulse values achieved vary from 2000 to 5000 lb seconds per lb.

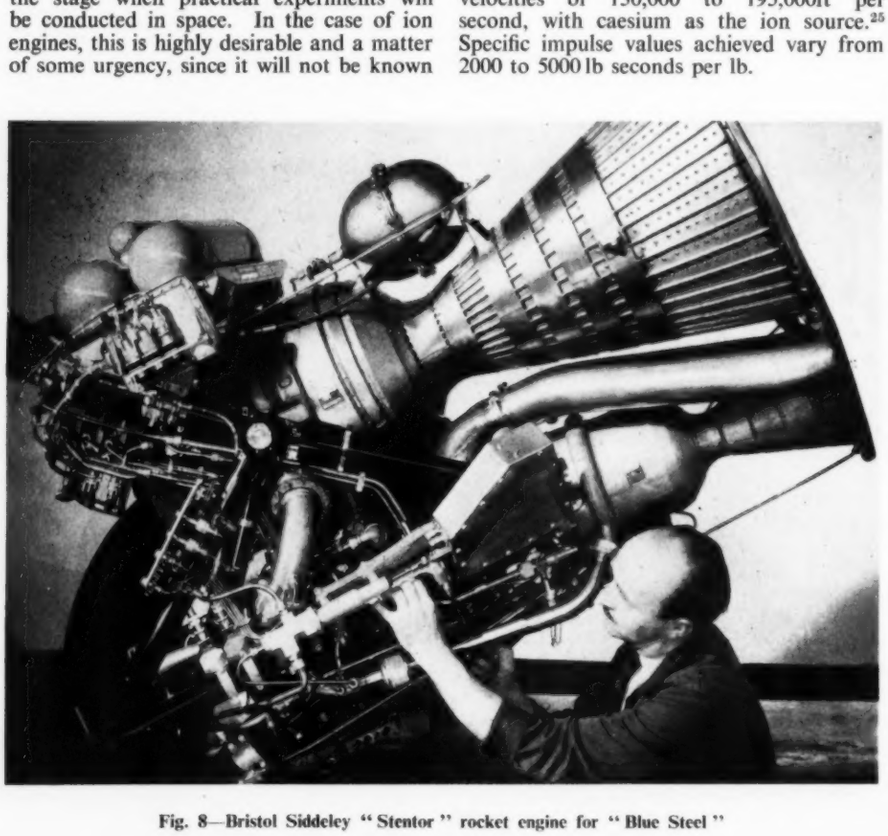


Fig. 8—Bristol Siddeley "Stentor" rocket engine for "Blue Steel"

The acceleration from ion systems is extremely small—about 0·04in per second squared ($10^{-4}g$)—but as it is continuously applied, very large increases in velocity are feasible on long flights, for example, of 100 million miles in one year. Vehicles of such low thrust can only escape completely from the Earth's gravitational field by (*a*) boost into orbit by a chemical rocket (or later, a nuclear upper stage); (*b*) starting up the electric propulsion system in orbit; (*c*) gradually building up velocity from orbital speed of about 18,000 m.p.h. to the required escape velocity of about 25,000 m.p.h., while executing a series of expanding

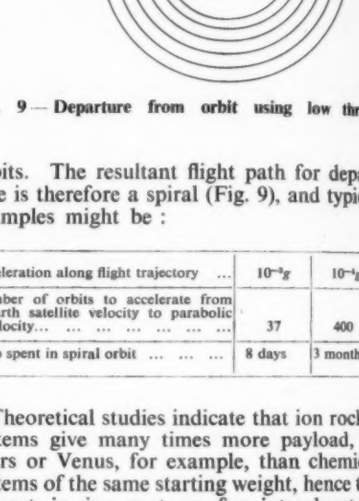


Fig. 9—Departure from orbit using low thrust

orbits. The resultant flight path for departure is therefore a spiral (Fig. 9), and typical examples might be :

Acceleration along flight trajectory ...	$10^{-3}g$	$10^{-4}g$
Number of orbits to accelerate from Earth satellite velocity to parabolic velocity...	37	400
Time spent in spiral orbit	8 days	3 months

Theoretical studies indicate that ion rocket systems give many times more payload, to Mars or Venus, for example, than chemical systems of the same starting weight, hence the interest in ion systems for interplanetary probes. When the problem of efficient neutralisation of the ion beam is solved, power efficiencies in the region of 80 per cent should be possible. Current ideas on neutralisation favour the use of another electrode, held at the potential of the vehicle hull, at the point of exit, to inject electrons into the exhaust beam. The first flight tests of an ion system may be made in orbit in 1962.

Industrial concerns have concentrated almost exclusively on caesium-to-tungsten contact ionisation. The N.A.S.A. Lewis Research Centre recently reported work on an alternative system, using electron bombardment of mercury vapour as ion sources.[28] The production of ions by the electron bombardment of mercury vapour is said to offer greater mechanical simplicity, reliability and efficiency, but the bombardment method has not yet reached such advanced development stages as have tungsten ionisers. In the Lewis Research Centre motors, the maximum power efficiency achieved was 87 per cent—about 27 per cent greater than present tungsten systems—propellant efficiency was over 80 per cent, and specific impulse reached 5500 lb seconds per lb with a 567W power source. Maximum thrust achieved during the tests was about 0·015 lb with a specific impulse of 8000 lb seconds per lb. This method uses a hot filament in an ionisation chamber to bombard entering mercury vapour with high velocity electrons, the direction of which is controlled by a magnetic field to keep them away from the walls and increase the probability of ionising collisions.

The system is by no means restricted to the use of mercury vapour as working fluid.

In the electromagnetic group, the Plasma Propulsion Laboratory of Republic Aviation Corporation have run a pulsed plasma pinch engine continuously for 118 hours with 0·01 lb thrust, with 90 deg. Cent. as the maximum operating temperature and an efficiency of 25 per cent.[12] The work demonstrates an advance in efficiency, maintained over a long running period, due to care in electrode design and in control of current and gas. The motor effects two "pinches" per second, using nitrogen. The gas first enters a plenum chamber opening into the electrode region, and when the nitrogen density in the electrode area reaches the conductive level, a condenser bank releases current. The gas is then "pinched," passes through the nozzle, and the cycle commences again. Such motors as these, however, are a long way from practical application, for they require considerable further research into magnetohydrodynamic flow, and such heavy and complex auxiliaries as high voltage condenser banks, and electromagnetic coils.

At a recent American Rocket Society meeting, however, a new technique for the acceleration of neutral plasmas was reported. The technique, developed at R.C.A., uses radio frequency power to produce an electric field which varies sinusoidally in time while remaining fixed with regard to space. When radio frequency is applied to a cylindrical electrode, the neutral plasma passing through it is accelerated towards the low-field region if the applied frequency is greater than the critical frequency of the plasma itself. At the R.C.A., a thin mercury plasma was accelerated from about 16,400ft to 82,000ft per second, with a radio frequency of 140 Mc/s, while the electric field was raised from 0 to 430V per inch. Should this technique be shown promising by further development, it could eliminate the need for some of the heavy auxiliary equipment required to produce magnetic field acceleration of plasmas.

Meanwhile, a good deal of research and development is being done on sources of electrical power. Nuclear and solar sources appear to be the more promising, and are likely to remain so for some time to come, since they offer reliability and minimum weight advantages, but conventional battery supplies may be used for the first flight tests of very small ion motors. Batteries will, in any event, continue to be used for storage when short bursts of high power are required from a small but steady supply, and with most solar cell systems.

Silicon photovoltaic cells have already been used in a number of satellites and space probes. They are at present capable of an efficiency of about 10 per cent, but output decreases at a rate of about 0·6 per cent per deg. Cent. above room temperature, making it necessary for banks of cells to be designed for maximum heat dissipation. This reduces the output obtained in practice to about 10W per square foot—the theoretical output, with the solar radiation flux at normal incidence outside the Earth's atmosphere amounting to about 130W per square foot, would be 13W per square foot. At lower temperatures the efficiency increases until about −100 deg. Cent., when it becomes virtually constant. The power obtained is simply dependent on the total area of cells exposed to light, but whatever the power, it is available for an indefinite period. Unfortunately, solar cells are more subject than any other power system to damage from cosmic radiation effects and micrometeorites.

The Tapco Group of Thompson Ramo Wooldridge Inc. have recently received a contract for the development of a 3kW solar turbogenerator system under Project "Sunflower." The 32ft diameter mirror will unfold in petal-shaped segments. As remarked earlier, it is planned to use this system to power an arc-jet of 0·01 lb thrust for attitude control and orbital correction of satellites. Solar heat will be focussed on to a small boiler containing mercury, which will be cycled through a turbogenerator. Total weight will be about 700 lb, yielding a little over 4W per lb. Life is dependent mainly on the reliability of the turbogenerator. Some form of solar-seeking device will be needed, but this is within the present state-of-the-art.[29]

A solar-powered thermoelectric generator of 100W output is being built by Hamilton Standard Division of United Aircraft under U.S.A.F. contract. Nine hundred aluminium reflectors, each 4in in diameter, will focus solar heat on the ends of thermocouples in the reflector centres. The 100W model will have a total area of about 100 square feet, but the Company is also planning to build a 1·5kW model. Thermoelectric units have no greater efficiency than solar cells, and an assembly such as this would be considerably larger and heavier than either solar cells or the "Sunflower" solar turbogenerator for similar outputs. The only advantage would seem to be less susceptibility to damage by cosmic radiation and micrometeorites.

The soundest prospects in the nuclear-electric field are offered by the Space Nuclear Auxiliary Power (SNAP) series. The odd-numbered SNAP units, such as the SNAP-3 version yielding 3W first publicised in January, 1959, use radioactive isotopes. SNAP-2 (3kW for one year) and other even-numbered units employ nuclear reactors. In order to minimise the danger of spreading radiation when vehicles so powered re-enter the atmosphere, the SNAP units have been designed to burn up on re-entry, so that by the time an altitude of about 100,000ft is reached the nuclear fuel would be reduced to particles of about micron size. The design, however, should allow the units to withstand launching hazards of damage due to impact or even booster explosion and fire without exposing the reactor core, but it is further planned to use a means of ejecting SNAP units from vehicles which fail at launch.

The advantage of a nuclear-turbogenerator system such as SNAP-2 is that it will provide a reliable and well-regulated supply of 3kW for about a year, regardless of the orientation of the vehicle. The weight of the system itself, however, is about 600 lb, and with the addition of minimum shielding —assuming the instrument payload to be resistant to radiation—the weight could be 900 lb (actual shielding weights vary with design).[30] This amounts to only a little over 3W per lb. With a normal electronics payload, e.g. containing transistors, the extra shielding may put the total weight up to 1200 lb, yielding only 2·5W per lb. Further, the rest of the vehicle would virtually have to be designed around the power unit, for optimum shielding reasons, because part of the vehicle skin must assist in radiating away excess heat, and in order to obtain correct mass balance. However, the system is far more compact and reliable than any other for this power, and requires no orientation: a great advantage over Project "Sunflower" with its 32ft-diameter focussing mirror which needs a solar-pointing device. The SNAP-8 turbogenerator should be ready in its 30kW version before 1965, and a 60kW version is also projected—much higher powers up to 1MW may be the subject of feasibility studies soon.

SNAP-10 is a 300W thermoelectric generator. Apart from their longer life due to absence of moving parts, thermoelectric units can take greater advantage of reactor heat than conventional generating equipment. Even with new materials, however, efficiency is only about 11 per cent, and there is still need for the discovery of materials which will retain their thermoelectric properties at very high temperatures.

The caesium vapour thermionic converter offers interesting possibilities, but it is still in the early stages of development at present. A model made by General Atomic Division of General Dynamics Corporation contains a "thermionic emitter" of uranium carbide and zirconium carbide. The generator, consisting of emitter and collector, is inserted into a reactor, the heat from which causes electrons to be "boiled off" from the emitter. Caesium vapour is sealed between the emitter and the collector in order to become an ionised conducting plasma and thus increase the efficiency, but this is still at present less than 10 per cent. The A.E.R.E. is doing research on converters of this type in the United Kingdom. Other types of thermionic converter (in effect, small unpowered diodes with cathodes heated) are also of very low efficiency (about 1 per cent), though they have a greater temperature range than thermoelectric units, being capable of use at 1000 deg. Cent., and G.E.C. have a 1W unit of squat disc-shape to show as the latest state of development.

A.V.C.O.'s Everett Research Laboratory and Westinghouse Electric have each produced 10kW models of magnetohydrodynamic generators using an ionised gas, possibly hydrogen, as the conductor. Research in the U.K. is concerned purely with industrial applications at present, and some universities are working in the field, also firms like Rolls-Royce and A.E.I. (Manchester) and establishments like the A.E.R.E. and the Central Electricity Generating Board. Materials which are easily ionised, e.g. caesium or potassium, can be added to the gas to improve conductivity. High temperature materials provide the main problems apart from magnetohydrodynamics. Theoretical efficiency is about 60 per cent, which is some 20 per cent higher than conventional generators.

Fuel cells are a long way from practical use. They have a theoretical efficiency of about 50 per cent, no moving parts, are capable of operation at low temperatures and give high output for their weight. Various types are in development, for example, the Allison Division of General Motors has run a laboratory model of a liquid metal fuel cell for an hour, and such a cell could be used in conjunction with a nuclear reactor, the metals serving as coolant.

For minimum weight and power from about 2kW onwards, turbogenerator systems offer the best promise of presently available methods: they have long development time behind them and hence good reliability, with the higher power capabilities required for electric propulsion. Reference 31 gives a review of power requirements up to 1970.

Nuclear

Following the successful first ground test last summer of the "Kiwi"-A-1 test-bed version of the Project "Rover" nuclear rocket, "Kiwi"-A-2 and 3 have been tested with different reactor cores. Nuclear booster stages seem to be a long way from

development, and N.A.S.A. and the Atomic Energy Commission are working towards lightweight nuclear engines and test vehicles, with the object of using a nuclear upper stage of 700 lb to 800 lb seconds per lb specific impulse in late versions of " Saturn " from about 1965. With a nuclear upper stage " Saturn " could place payloads of 72,000 lb in a 300-mile orbit, 32,000 lb in a twenty-four-hour orbit and send nearly 15,000 lb to a soft landing on the moon, according to Wernher von Braun. Some of the problems are : lightweight insulation for the liquid hydrogen and a means of pre-cooling the tank before filling, pressurization to prevent sloshing, and a nozzle with heat transfer characteristics far greater than those of chemical rocket nozzles.[15, 32] A solid fuel type of " Kiwi "-A, using part of the reactor as nozzle, is also under study. Surprisingly, some interest is still being shown in Project " Orion," which envisages the use of a succession of small nuclear explosions to propel a very large rocket with an " ablative " base.

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(To be continued)

FIRE PROTECTION MATERIAL.—Turners Asbestos Cement Company, Ltd., has recently completed tests on asbestos board used as a protection of aluminium decks against fire, and independent tests have been carried out by the Department of Industrial and Scientific Research. In the tests sections of aluminium alloy deck were protected by the new method and heated from below for one hour. After five minutes the temperature on the underside had risen to 600 deg. Cent. and continued to increase to over 900 deg. Cent., while at the end of one hour the temperature of the upper surface of the deck had only risen to a little above 100 deg. Cent. Thus the material and method had achieved the standard set by the International Convention for the Safety of Life at Sea for fire resisting divisions on passenger ships.

Test Equipment for Washing Machine Motors

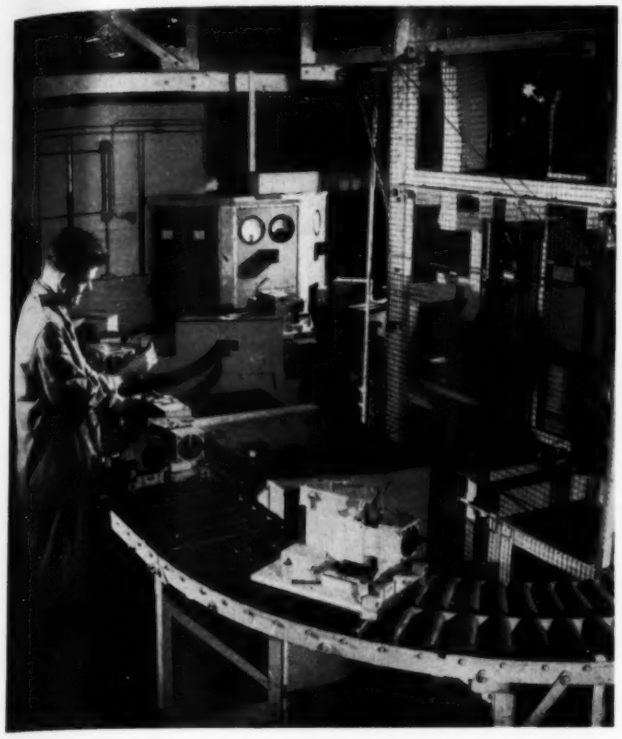
A new production line has been installed at the Merthyr Tydfil factory of Hoover (Washing Machines), Ltd., for the manufacture of the recently introduced " Keymatic " automatic washing machine. Some £2,000,000 has been invested in installing special purpose equipment based upon the latest production techniques for the new machines. A new building covering 100,000 square feet housing the production line has increased the factory area to some 750,000 square feet. Motors for the washing machines are supplied from the company's Cambuslang factory and in this article some notes are given on the automatic testing plant which has been installed.

AN interesting part of the manufacturing programme recently completed by Hoover (Washing Machines), Ltd., for the production of the new " Keymatic " automatic washing machine has been the section concerned with the making and testing of motors at the Cambuslang factory of Hoover (Electric Motors), Ltd. The reversible geared fractional horsepower main motor has a direct drive taken from one end and a second drive through a worm reduction unit at the other end, a reversing switch enabling the drive to be taken in both directions. A second small motor pump unit of special design is also incorporated in the machine. For the manufacture of these motors transfer lines of special machines have been installed and we are informed that the large motor production time is about one man-hour per unit and for the motor pumps only just over 0·4 man hours.

When the production programme for the motors was being devised it was decided that a considerable amount of money could be saved in providing advanced techniques in testing and some of the equipment used for this purpose is illustrated on these pages. When it reaches the end of its assembly line each main motor is first run-in. For this purpose it is placed on a test tray which incorporates a transformer providing twenty voltage tappings to cover the range of motor ratings required for machines to be supplied to this country and overseas. Six leads from the motor are plugged into appropriate positions on the tray, power is switched on, and the motor moves into the test sequence, to first be carried up on a conveyor, around a run-in loop. Half way along this loop is a switch which reverses the motor so that in the ten-minute period of travel through the loop, the motor has a preliminary run of five minutes in each direction.

At the end of the loop the motor tray carriers descend to floor level where each tray is lowered on to a short run of chain conveyor which transfers it over to a pneumatic pusher. This pusher moves the tray on to one of the sections of an annular rotating table where main testing is carried out. On this table the motor is first connected automatically to the power supply and then presented to five test stations in sequence. At each station a motor is connected and disconnected automatically for the relevant test. At the last test station a pneumatically operated door is raised and the motor passed through into a silence room where, apart from testing for noise, the operator also watches an accept-reject console. Whilst each motor has been going through test stations the memory circuit of a control equipment registers the results and, if there have been no faults, the motor is passed through

Loading main motors on to carriers at entry of running-in circuit



Main motors being removed from carriers at acceptance station. The rotary table multi-station testing equipment can be seen in the background

another door to the unloading station. If any motor is faulty a visual indication is given on the console and a pusher operates to transfer the motor to a short reject conveyor leading to a section where the faults are rectified. The memory circuit of this equipment, in addition to passing or rejecting each motor, incorporates a device which punches a code signal in a card on each tray, at each test station. This card shows where the fault lies when a motor passes into the rectification section. In this inspection plant the test cycle is only twenty-two seconds per station so that, with the line fully loaded, a completely tested motor comes off every twenty-two seconds.

The automatic test equipment for the pump motor units was built by Wilflo Products, Ltd., of Glasgow. The run-in section in this set-up, as can be seen in the first illustration, is arranged in the form of a wheel with radial compartments. Motors mounted in pairs are placed in the compartments and as the wheel rotates over a ten minute cycle they are run in and their insulation tested. Any motor failing on test is indicated by the illumination of a lamp above the operator's position when the faulty motor reaches the unloading position. One pair of motors comes off the wheel every forty seconds and an interlocking system makes it impossible for the operator to ignore a fault indication.

From the running-in sections, the motors pass along a conveyor to a special cubicle in which tests are carried out with the motor pump unit under actual operating conditions. On normal production all tests are carried out in this cubicle automatically, with a controlled timed cycle of thirty-five to forty seconds for a complete test. For this testing sequence an operator places a motor in the fixture, connects its leads, and also connects the pump inlet and outlet to two quick-acting collets. When the correct voltage rating for the motor has been selected and a push button depressed the whole test cycle is automatically carried out.

The main water valve first opens and primes the system with water, releasing any trapped air. Illumination of an indicator lamp then shows that the power has been switched on and a continuity test for the motor windings is initiated, an indicator lamp showing that the test is in progress. If there is a failure, the equipment will not continue its cycle, but shuts down ; the water system is cleared ; the hose connections are released ; an audible signal is given ; and no further testing can be carried out until the reset button is pressed. Following continuity test, the equipment proceeds automatically to test the pump for minimum flow at run-up volts, followed by a test for maximum flow at full load volts and, at the same time, the motor is tested for wattage. Indicator lamps show which test is in progress, and the equipment automatically shuts down if there is a fault.

To clear all traces of water from the tested motor pump unit after the water has been automatically drained, air is drawn through at high speed to purge it of any water adhering to the pipe walls or still remaining in the pump casing. The water system in this equipment is as elaborate as the electrical section, because the cycle has to provide for water to be supplied only when needed and a standard controlled head of water has to be maintained. The various by-passing arrangements of the water supply from one circuit to another are achieved by a system of valves and relays.

Motor pump units being run-in, in compartments of rotating rig. During the ten minute cycle in the rig the motor insulation is also tested and failure is indicated by signal lamps at the operator's station

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

PORCELAIN AND TOUGHENED GLASS INSULATORS FOR OVERHEAD POWER LINES (3·3kV AND UPWARDS)

No. 137 : 1960. Price 15s.

HIGH VOLTAGE POST INSULATORS

No. 3297 : 1960. Price 10s.

The new edition of B.S. 137 is a revision of the 1941 edition. It incorporates the addendum of 1946, in which insulator pins were standardised, and extends the range of standard string insulator units up to a specified minimum failing load of 42,000 lb. The test requirements are closely in line with those of Publications 75 and 87 of the International Electrotechnical Commission, which deal respectively with porcelain and glass insulators. The designs of ball and socket couplings have been revised and are now the same as those recommended in I.E.C. Publication 120. This change, while maintaining interchangeability with existing British designs, ensures complete interchangeability with string insulator units made in any of the principal manufacturing countries.

B.S. 3297 is a new standard and provides a specification for porcelain and toughened glass post insulators for the same voltage range as that covered by B.S. 137. The insulators specified in B.S. 3297 are designed to give rigid support to busbars, isolators and air-break switch parts in substations, and for similar applications. Mechanical and electrical tests are included to ensure that the insulators are suitable for these duties. The specification is closely in line with B.S. 137, B.S. 223, "High voltage bushings," and the draft recommendations of the I.E.C. on post insulators. Detailed information about post insulator units in common use in Great Britain is given in an appendix.

CONVEYOR BELTING FOR UNDERGROUND USE IN COAL MINES

No. 3289 : 1960. Price 5s. This new Standard specifies requirements for conveyor belting for underground use in coal-mines. It may also be applicable to other underground and surface installations where similar operational hazards exist. The publication lays down requirements for tensile properties, adhesion of plies, electrical and fire resistance, together with methods of test. It has not been found possible to specify limits for all properties, but additions will be made when suitable tests are available.

LETTERS AND LITERATURE

Letters to the Editor

ELECTRICITY GENERATION IN SCOTLAND

SIR,—I have read with interest the leader in your issue of March 17 about electricity generation in Scotland and thank you for the kind things written about the Board.

There is one small point, however, near the foot of column two (page 901), where I think you have gone wrong. You quote the cost per unit "sent out" for the C.E.G.B.'s stations as 0·606d. for 1960. This figure, however, only refers to the average works cost per unit sent out and includes nothing for fixed capital charges. In statement 6 of its report the Generating Board gives the total cost of generation per unit sent out in 1959-60 as 0·8616d. This point was touched on in a letter written by the Board's Chairman to *The Times* (published March 1, 1961) whose leader writer had overlooked the point.

GEORGE D. BANKS

North of Scotland
Hydro-Electric Board,
Edinburgh,
March 22, 1961.

[A very material point. The cost per unit sent out for hydro-electric stations of the Hydro-Electric Board, as quoted in the same article was 0·787d. for 1960.—ED. THE E.]

MILLIONS TO BE SAVED?

SIR,—After reading Mr. C. G. Dahl's letters I can only think that he has never seen a double track permanent-way with the rails removed. Once he had seen the disused Hull and Barnsley line which could provide an excellent reserved motor road for over half the distance from Hull to Manchester, I should be very surprised if he did not see the great possibilities that railway conversion has to offer. There are, of course, many other disused lines which could be made into excellent roads and once the public had sampled the benefits of 24ft to 30ft wide reserved roadways I think wholesale conversion would rapidly follow.

T. B. MURGATROYD

Harrogate,
March 21, 1961.

SIR,—In your footnote to Mr. Tuplin's letter (March 17) you state the present editorial position of THE ENGINEER on railway conversion: not convinced as to the validity of the overall project, but agreeing that any abandoned railway route should immediately be considered for conversion to a road. If this position is one which the majority of your readers would accept, then indeed the great amount of space given to the subject recently in your columns will not be regarded by the Railway Conversion League as by any means wasted. We have always accepted the view that some practical demonstration would be necessary before we could hope to carry the country fully with us on this great issue.

The steps which you advocate have an immediate practical relevance. The Minister of Transport has said that "There must be a purposeful slimming of the railways," and has added that this is "not an exercise which can be done once and for all. . . . It is a continuing process." Some indication of what this entails may be gleaned from the statement in the British Transport Commission's "Re-appraisal of the Plan for Modernisation," issued in July, 1959: "There will be a reduction of route mileage, of the order of 10 per cent, during the period 1959 to 1963." Though the Ministry of Transport did not accept this re-appraisal *in toto* the indications are that their present thinking is in terms of a considerably higher rate of closure of routes. A recent report has suggested that the figure may be as high as 20 per cent (nearly 4000 miles) by 1963.

The fate of the 20 miles of disused route required by the Norfolk County Council for conversion to roads (D. F. C. Vosper, March 17) indicates that little good-will or co-operation in the matter of converting further such lines can necessarily be expected from the British Transport Commission. Thus a very serious view must be taken of the provision, in paragraph 26 of the recent Government White Paper (Cmnd. 1248), which reads as follows:

". . . It is proposed to set up one or more organisations specially equipped to advise the Statutory Boards and the Companies and act for them as necessary, with the object of obtaining the best possible return, in connection with the development of their property, and the transfer or disposal, from time to time, of such as is no longer required for operational purposes."

There is evidently no present intention of regarding these irreplaceable routes, which are part of the national heritage and not the property of the British Transport Commission, as anything but items to be disposed of for as high a cash price as possible in order to improve the appearance of British Railways' accounts. The League intends to do all it can to draw attention to the danger inherent in these proposals and to obtain their modification before they become law. In this the support of all who appreciate the folly of frittering away rights of way at the present time is needed.

Dr. William Glanville (as he then was), head of the Road Research Laboratory, suggested in 1957 that traffic problem could only be met by a system of segregated routes, reserved for motor traffic. The League believes that ultimately and inevitably the "slimming" process now starting will involve the whole of the railway system. (We could, of course, be wrong and the railways prove themselves immortal!) If this belief is sound we can look forward to Dr. Glanville's vision becoming a practicable reality; but not if, in the meantime, vital parts of the railway system have been sold off, leaving the rest dismembered and useless.

There is a more subtle danger in the mere piecemeal conversion of disused railways into roads, if they were then to pass under the control of the 1285 highway authorities in Great Britain, and thus be lost as potential parts of the ultimate reserved system. The League believes that all these routes should be controlled by one special authority, which will decide the best use of them in the light of an overall long-term plan. This does not mean that conversion could not proceed as routes become available, or even that temporary arrangements could not be made for the use of such converted routes as part of the present road system. It would, however, ensure that we did not throw away, for the sake of immediate financial benefit or for any other reason, the priceless asset of the railway routes which our fathers bequeathed to us and in which lies the only alternative to our hopelessly congested and inadequate road system.

M. J. DOUGLASS,
Hon. Co-ordinator
Railway Conversion League,
Guildford,
March 17, 1961.

SIR,—I have, through recent years, followed the correspondence in your columns relevant to railway conversion, and whilst it is right and proper that the proposals and views of both sides should be heard, I find it hard to understand why a journal of such standing and reputation as THE ENGINEER should have been so misled as to apportion a great deal of valuable space to an exposition of the case of the Railway Conversion League. In your issue of March 3 Mr. Gordon England states, "nobody has put up a well-reasoned case in rebuttal of the facts." This, I submit with respect, is because the R.C.L. has no facts. Here we have—and I speak as an ex-member—a nebulous proposal, born of the daydreams of a handful of racing motorists, minor haulage contractors, and road construction outfits, supported by a wizard of statistics, none of whom have any experience whatever of public transport operation. It is significant that no other road organisations, such as the A.A. Roads Campaign Council, or Road Haulage Association, have seen fit to support the R.C.L.

I can hardly improve on the mundane and reasoned letters submitted by your correspondents who realise that railways, with all their drawbacks, remain an organised, efficient form of mass transport, safe and reliable, and likely to remain unsurpassed as such in the foreseeable future. Whatever point the conversionists pursue, they always conveniently omit reference to other important considerations. Only by treating each item in isolation can their case be made to appear feasible.

We are never told about such problems as cross-winds, all-weather reliability, breakdowns, and accidents, moving thousands of people to and from public meetings in a very short time, vehicle and staff schedules, single-track tunnels, operation of flat junctions,

level crossings, sleeping facilities, or how buses will keep to schedule when the converted railways are congested with private cars.

Neither does the League admit to continued expansion, extension, and improvement of conventional railways in all parts of the world. Even in the United States, the motorists' paradise, there is a growing awareness that public transport is essential, and entitled to priority. So in calling for roads, roads, roads, regardless of the consequencies, the R.C.L. is very much behind the times.

Much of the League's case is based on an estimated vehicle population of 14,000,000. in the middle 'sixties. Should this come about, and providing the Government has saved the surface of Britain from being 100 per cent roadways, those who do not wish to drive cars on roads congested to suffocating point will be able to travel with comfort and alacrity by train. I therefore trust, sir, that this pointless controversy will be terminated, and the idea of converting railways into roads once and for all, as it must surely be obvious that such proposals, when all factors are taken into consideration, are incapable of achievement.

E. RELTON

London, E.10,
March 11, 1961.

SIR,—The writers for and against Railway Conversion quickly get bogged down in matters of detail : most of them important, but still details. A famous field-marshal tells us to first strip our problems of details : then look squarely at the few main factors and the best course of action will be seen. The details will all fall into line. Herewith my "Monty" view of this question.

1. We have about 1,000,000 new motor vehicles each year.

2. Our capacity for building new roads is so inadequate that our road transport system will be jammed right up within five years. Result, industrial disaster.

3. Is there any solution ? Fortunately there is. The Railway Conversion League brings plenty of evidence to show that the whole railway system might be converted into controlled motorways. They claim that this would provide a first-class cheap transport system with inestimable benefits to all.

4. How can we know if they are right ? This vast question can only be answered by a full scale inquiry and report on all its aspects.

5. No such inquiry has been held. The Government seems satisfied with its present road plans and is chiefly concerned to keep the railways in being regardless of the cost.

6. This is not just a question of "Road *v.* Rail," or even of "Millions to be Saved." The whole industrial life of the nation is at stake. This inquiry should be held now. I believe it would find for complete conversion of railways into roads with the utmost despatch.

7. Whatever we may argue about it the mounting pressure of the traffic on the roads will very soon bring this great issue to a head.

H. E. MORSE

Weymouth,
March 14, 1961.

NUCLEAR POWER PLANT STEAM CONDITIONS

SIR,—It is rare in this well-informed age to see a request for information from your readers in your correspondence columns, but if you do not consider the practice too archaic I should be grateful for the opportunity to put a query to which I have failed to find an answer elsewhere.

My question concerns the steam cycle used in British nuclear power stations, where the pressures, and more particularly the temperatures, would have been considered modest in the coal-fired stations of thirty years ago. I appreciate that this is due to the limits imposed by the present state of reactor design, but cannot understand why these reactors are not used to generate saturated steam at twice the present pressure for superheating to a modern temperature in a separate coal- or oil-fired superheater ; this superheater could use an air heater and economiser, and should have an efficiency not far short of a modern boiler. Without quoting my rough figures, it is apparent that this would vastly enhance the station efficiency and the fuel burned in the superheater would give extremely good value for money. I have not sufficient data to consider this aspect, but I suspect that the capital cost per kilowatt would also be lowered.

This system has been mentioned from time to time, and the Americans have adopted it at Indian Point, though ironically enough they have little need yet to consider the economics of their nuclear stations. I have heard various reasons for the British failure to use it, such as the difficulty of control, the distance of the stations from fuel supplies, and even that it would be considered unethical to use anything but nuclear fuel in a nuclear station, but none of these arguments seem adequate.

I should be most grateful to any engineer who could tell me why fossil fuel fired superheaters have been dismissed in this country. There must be many in the A.E.A., the C.E.B. and the consortia who have the answers, but my only contact with these industries is through your columns.

W. MELVILLE

Birmingham,
March 9, 1961.

METROPOLITAN LINE WIDENING

SIR,—"The lady protests too much, methinks." Where one reason, supported by figures, would have been sufficient, London Transport have chosen to throw the whole textbook at me regardless of whether or not it can all be properly applied in this case.

I will content myself with two points.

How much rolling-stock do London Transport claim that they can save by the use of their fourth track? They are always impressing on us the shortness of the rush-hour —one hour in the morning and one and a half hours in the evening are the official figures. Under the present system some trains terminate at Harrow and the journey is short enough to enable one or two to be sent back to the starting-point in time to make a second journey within the rush-hour. With the extension of these trains to Amersham, with a journey time of over fifty minutes, it is difficult to see how a second journey can be made. The nearer terminating point of Watford is ruled out of this argument because it will have no access to the fast tracks.

This brings me to my second point—flexibility. The three-track scheme would provide a complete duplicate service to the stations on the section in question. Under the four-track scheme these stations, together with Watford and Croxley, will have no access to the fast lines and will therefore have no service at all if one of the slow lines is blocked.

London Transport appear to be excessively sensitive to the suggestion that the fast lines should be reserved for British Railways. Could it be that in this direction their arguments in support of their scheme are even more threadbare?

E. J. R. KAY

Rickmansworth,
March 18, 1961.

Book Reviews

Operations Research and Systems Engineering. Edited by C. D. FLAGLE, W. H. HUGGINS and R. H. ROY. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 116s.

IN Great Britain the term Operational Research has long been fought over, but a working definition of O.R. has slowly emerged which is being accepted as reasonable. This definition or description might be worded as follows :

Operational Research is a method which in a consultative capacity provides management with material from which it can make better decisions than would otherwise have been the case in an ever-widening field of technical, sales, distribution, and other problems, using mainly powerful new mathematical techniques that have been developed during the past twenty years but also employing the team approach whereby advantage is taken of the special knowledge of experts in their own fields.

Admittedly, the above definition is broad based, and overlap is entirely possible with pure research, work study, organisation and method, &c. : The normal British view is, however, that this overlap is not necessarily an evil, and there are, for instance, Work Study departments which include an Operational Research section, and vice versa.

The above introduction is necessary before considering any American book on Operational Research or any of its brothers and cousins, as the point of view in the U.S.A. is different from ours. Possibly because of the rise of specialists in their own particular branch of management science, there is the curious spectacle that whereas in Great Britain no one worries too much about the exact definition of Operations Research, &c., in the United States there are Operations Research, Industrial Engineering, Statistical Quality Control, and now Systems Engineering, and great pains are taken to define the particular sphere of each of these. In Goode and Machol's *System Engineering*, reviewed some time ago in these columns, the authors blandly state that Operations Research is a part of System Engineering, and then provide what is, in fact, an excellent textbook on O.R. techniques, plus sections on computers and feedback theory. In the work at present under review a different method has been adopted. In Part 1 an attempt is made in alternating chapters to set out what O.R. and Systems Engineering

LETTERS AND LITERATURE *(continued)*

are respectively. The basic definitions, that few in this country would accept, are :

" The O.R. team is concerned with operations *per se*, and is more likely to be concerned with operations in being than with operations in prospect. Systems engineers are . . . more likely to emphasize the machines than the procedures by which the machines are used. Furthermore, they are more likely to be engaged in the design of systems yet to be rather than the operations of systems in being."

This introductory Part 1 is not very long and brings us to Part 2, the excellent main part of the book, " Methodologies, " in which no further attempt is made to keep up the rather artificial distinction between O.R. and Systems Engineering. Part 3 closes the book with four real life case histories.

From the cover of *Operations Research and Systems Engineering*, one would gather that there are three authors. The book is, in fact, however, an assembly of lectures given at Johns Hopkins University, Baltimore, by members of the staffs of that and other universities. These have been edited to form a coherent whole, but there is some lack of continuity, and the individual contributions vary in value. The proportion of very good to medium (none are bad) is, fortunately for the reader, high.

The contents of Part 2 may be summarised as follows : basic statistics, statistical quality control and statistical design of experiments ; stock control, queueing, linear programming and theory of games ; digital computers ; symbolic logic ; human engineering (ergonomics) ; information theory; network theory; feedback theory. The above is a comprehensive list which may even sound formidable. " Formidable" is not, however, a fair description. All the contributors have contrived, without any writing down or condescension, to make their subjects as simple as they can be made, and to keep where possible the mathematics to ordinary calculus level. The following selections, though not made at random, are intended to give the general outlook.

" Linear Programming, " which is in effect the finding of a " best " solution, least costly, largest profits &c., for a complex business situation involving limited resources, by what are in effect differential methods, has been talked about for years, but little used on this side of the Atlantic, except by animal food manufacturers who all use it to achieve the most nutritive-economical mix, oil refiners who use the method for " cracking " proportions, &c., and iron, steel, and non-ferrous manufacturing companies who apply L.P. to the best use of resources from several mines, &c. In America the method appears to be more widely used and to be successful. The author of the chapter on linear programming advances the interesting theory that its success is linked with progress in economic theory.

Queueing Theory was worked out as long ago as 1907 by A.K. Erlang in Copenhagen, but it is only during the past few years that it has been realised how useful it can be when applied to congestion problems and machine interference. The author of the section on queueing succeeds in explaining the theory in simple terms, and he then proceeds to give several practical examples of its application. He also points out that it may not be possible to apply the theory in its purest form to an actual situation, and that it may be sensible to make a " Monte-Carlo " mathematical simulation model as explained in a subsequent chapter, and experiment on that model.

The chapter on Simulation Techniques takes much the same line. The author points out that if an actual situation cannot be altered, which is usually true of a management policy relating to production, for instance, it should be possible to make a mathematical simulation model, and experiment with different policies on that model. He then gives an example in line with the advice of the queueing chapter of a simulation of a single channel queue.

The connection of Symbolic Logic with Operational Research may seem a little remote, but this is far from being the case. Some understanding of symbolic logic is essential for the " And, " " Or, " " Not, " being the basis of computer design and use. Furthermore symbolic logic, while not yet fully developed as an O.R. tool, has been used to help solve complex situations. The author of the section puts forward his own ingenious method of forming a " truth matrix "—and he establishes a case for the method by solving twovery complex logical puzzles.

The four final chapters of Part 2 soar into more lofty theoretical regions, dealing with Information Theory, Flow-graph Representation of Systems, System Dynamics, and Feedback. These chapters are not recommended to the beginner in Operational Research but are none the less important. Information Theory is useful to more than telephone and radio technicians, flow-graphs provide a graphical shorthand presentation of complex algebraic sets of equations, and recent advances in network theory with which this method is linked are considered in France to be important from the practical angle of providing a relatively simple method of solving complicated situations. Systems Dynamics links O.R. with the analogue computer. Feedback is a big subject in itself, developed by electrical engineers but having much wider implications, particularly in view of the growth of automatic control of machines and of complete plant.

Part 3 gives, as has been mentioned, four real life case histories, a study of a hospital's organisation and work, an analysis of newspaper operation with particular emphasis on the time factor, an examination of the cost and value of reports in a telephone company, an unusual one by the way, and a military example, the simulation of tactical war games. This exhortation is followed by practical example.

Die Eigenschaften des Betons. By O. GRAF. Second, revised edition by W. Albrecht and H. Schäffler. Berlin–Göttingen–Heidelberg : Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3. Price DM.52.50.

THE original edition of the present work by one of the pioneers of modern concrete appeared twelve years ago. Following the author's death it has now been revised and brought up to date by two close associates. On the basis of a wealth of experimental results the work presents a discussion of the various kinds of plain and special concretes, the cements and aggregates employed, the design of compositions to meet particular specifications, the effects of mixing and transporting, and the various methods of placing and consolidation. The physical properties find detailed consideration in the second half of the volume, which also contains an account of such recent developments as lightweight concretes and stabilised soils. The book concludes with a chapter on the testing of concretes and their basic materials.

D.S.I.R. Research Grants, 1961. H.M. Stationery Office. Price 1s.

D.S.I.R. Studentships and Fellowships, 1961. H.M. Stationery Office. Price 1s. 9d.

THE first of these two pamphlets, just published, provides full details about the grants for special researches awarded by the Department of Scientific and Industrial Research. They are intended for investigators who are of acknowledged standing. The pamphlet outlines the ruling policy, gives details of the kind of subjects considered suitable and describes the procedure for applying for grants. The Regulations under which grants are made are given in detail.

The other pamphlet provides similar details about post-graduate awards to enable promising young students to continue their training beyond a first degree and about awards to others who have already had post-graduate training who have shown special aptitude for original and independent research and who appear likely to benefit from an opportunity to develop the aptitude further. Three types of award are available—research studentships, advanced course studentships and research fellowships. Full details of eligibility, how to apply, nature and amounts of awards and grants, &c., are given for each of the three types and there are references to awards tenable abroad and to N.A.T.O. studentships and fellowships.

Innovations in Building Materials. By MARION BOWLEY. Gerald Duckworth and Co., Ltd., 3, Henrietta Street, London, W.C.2. Price 70s.

DR. BOWLEY is Reader in Political Economy in the University of London, and this book is an economic survey. It is one of a series of studies made by members of the Department of Political Economy of University College, all based on the proposition that continued economic progress depends on the capacity of an industry to introduce new products and processes in rapid succession. Consequently, technical matters are not dealt with in any detail. Nevertheless, since technical innovation both influences and is influenced by economic conditions, this very detailed study of building materials contains much of interest to anyone whose concern with the building industry is not narrowly technological.

The survey deals particularly with bricks, cement and concrete, glass and other claddings, asbestos cement sheet, and aluminium, and in its search for causes and effects brings to light some interesting human as well as economic factors. It is, after all, often the man with a good idea and the business ability to exploit it who influences an industry profoundly, though that is far from being the

only reason why changes come about. Sheer necessity in order to survive, chance discovery, planned research, external and apparently unconnected events, all play their part from time to time, as the present survey shows.

Die Kleinkältemaschine. By R. PLANK and J. KUPRIANOFF. Berlin–Göttingen–Heidelberg: Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3. Price DM. 52.50.

DESIGNERS and users of small refrigeration plant will find much of interest in this book which, after being out of print for several years, has now been republished in a revised second edition. The contents have been brought up to date so as to include the many important developments which have taken place in the last decade, both in Europe and in the United States. These include new applications, new automatic controls and special designs as well as advances with sealed compressors and absorption units.

Production of Wide Steel Strip. Special Report No. 67 (of a symposium held in London, May, 1960). The Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1. Price 65s.

MOST of the world's production of steel sheet (except for special-purpose grades) is now by the wide strip process. Steel sheet, being the basis of so many durable consumer goods, is one of the symbols of a high standard of living, and it is difficult to imagine how the demand for sheet could be met other than by the wide strip process. If living standards are to be raised, production of sheet will rise with them, and production processes are to-day of great interest and significance. One of the difficulties inherent in the wide strip process is the very high capital cost of the equipment, and there is considerable interest in possible short cuts and simplifications which would reduce the cost. There are operating problems, too; although the wide strip process works at a very high degree of technical efficiency, those concerned with its running are well aware that if certain limiting factors could be eliminated, outputs could be increased.

The symposium worked with wide terms of reference, taking into account not only the rolling—hot and cold—of wide strip, but also the production of the steel from which the strip is made, and the surface treatment, by tinning, galvanising or plastic coating, of the finish-rolled product. Moreover, the symposium was international, with contributions from Australia, Holland, Italy and the U.S.A. as well as the United Kingdom. Plant manufacturers as well as steelmakers took part. The result is a detailed review of modern practice and equipment which shows how closely mechanical and electrical engineers have co-operated with steelmakers and metallurgists to put into operation a highly efficient process with large outputs of consistent quality.

Mechanised Cutting and Loading of Coal. By R. SHEPHERD, B.Sc., Ph.D., F.G.S., M.I.Min.E., and A. G. WITHERS, B.Sc., Ph.D., Dip. Met. Min. Odhams Press, Ltd., 96, Long Acre, London, W.C.2. Price 50s.

DURING the past decade, with the acceleration of mechanisation at the coal face in the mines of this country, a considerable amount of information on the different types of machines developed has been published in technical and trade journals. This information is, however, widely scattered and to get an overall impression the student has to seek from many sources. For this reason a book such as this, which gives a detailed account of the many classes of machines and equipment in service and under development, provides a particularly welcome addition to the technical library. It opens with a concise introduction to the reasons for, and economics of, coal face mechanisation followed by a brief historical review. After giving the classification of coal-cutting machinery and the principles of coal breakage, the authors describe in detail the various types of machines and equipment, their features in relation to particular operational problems, and typical installations. Some interesting notes on experimental machines developed in this country and overseas and a general chapter on the subject give an indication of the trend of development, whilst a chapter on other means of coal-winning deals with pneumatic picks, hydraulic bursters, "Cardex" and "Hydrex," compressed air systems and pulsed infusion methods. The subject matter is well supplemented with photographs and drawings and a list of references which concludes each section assists the reader who wishes to obtain further detailed information.

Aerodynamik des Flugzeuges. Vol. II. By H. SCHLICHTING and E. TRUCKENBRODT. Berlin–Göttingen–Heidelberg: Springer-Verlag, Berlin-Wilmersdorf, Heidelberger Platz 3. Price DM.61.50.

PUBLICATION of the second volume now completes the issue of *Aerodynamics of the Aeroplane*, of which the first volume made its appearance in 1959. While the first part of the work dealt with fundamental fluid and gas dynamics with special reference to aerodynamic applications, including wings of infinite span (profile theory), the present volume presents the theory of wings of finite span, the aerodynamics of fuselage and control surfaces and the mutual interference of these components. Appropriate references are given in the text to the very large number of papers and articles which have appeared in this field during the last few years. Throughout, the book considers the full range of Mach numbers which are met with in current practice.

Books of Reference

Jahrbuch der Elektrowärme, 1958–59. General Editor: Professor Dr.-Ing. Harald Muller. Essen: Vulcan-Verlag. Dr. W. Classen, Essen, Haus der Technik, Hollestrasse 1g. Price DM.68.—The third *Yearbook of Electrical Heating* represents in compendium form the state of the art at the beginning of 1959. International literature is covered in the following main fields: pig iron and steel production; copper and light alloys; high duty metals and alloys, and heat resistant materials; core production; heating and soaking of steels and non-ferrous metals; welding, cutting, and electro-erosion; hard and soft soldering; enamelling and galvanising. These sections are prefaced by fully illustrated symposia which are to be brought up to date every two years. All contributions are given their U.D.C. classification numbers. The group of countries whose literature is surveyed has been enlarged by the addition of Japan. Reference is facilitated by a detailed subject index listing for each entry the section and page number as well as mention previously in volumes of the year-books.

Books Received

Structural Concrete. By Dr. Kurt Billig. Macmillan and Co., Ltd., St. Martin's Street, London, W.C.2. Price 84s.

The Science of Wealth. By C. F. Carter. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 14s.

Grundzüge der Strahlenschutztechnik. By Thomsa Jaeger. Berlin-Wilmersdorf, Heidelberger Platz 3 (West Berlin). Price DM46.50.

A History of Flow Measurement by Pressure-Difference Devices. George Kent, Ltd., Luton, Bedfordshire. Price 10s.

Aerodynamic Capture of Particles. Edited by E. G. Richardson. Pergamon Press, Ltd., Headington Hill Hall, Oxford. Price 50s.

The Directory of Opportunities for Graduates, 1961. Cornmarket Press, Ltd., 1, Lower James Street, London, 1. Price 8s. 6d.

Fundamentals of Digital Instrumentation. By D. S. Evans. Hilger and Watts, Ltd., 98, St. Pancras Way, London, N.W.1. Price 7s. 6d.

The Construction of Gothic Cathedrals. By John Fitchen. The Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 63s.

Experimental Plastics. By C. A. Redfarn and J. Bedford. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 22s.

The Brittle Fracture of Steel. By W. D. Biggs. Messrs. Macdonald and Evans, Ltd., 8, John Street, Bedford Row, London, W.C.1. Price 70s.

Water Power Development. Vol. 2. By Emil Mosonyi. Publishing House of the Hungarian Academy of Sciences, Budapest. Price 15.00 dollars.

Rules and Regulations for the Construction for and Classification of Steel Ships. 1961. Lloyd's Register of Shipping, 71, Fenchurch Street, London. Price 42s.

Rohrleitungen in Dampfkraftwerken und dampfverbrauchenden Betrieben. By Fr. F. Wiese. VDI-Verlag G.m.b.H. (22a) Dusseldorf 10, Postfach. Price DM.36.80.

Britain—an Official Handbook. 1961 edition. Prepared by the Central Office of Information. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 25s.

International Dictionary of Applied Mathematics. By W. F. Freiberger. D. Van Nostrand Company, Ltd., 358, Kensington High Street, London, W.1. Price 187s. 6d.

Impact—the Theory and Physical Behaviour of Colliding Solids. By Werner Goldsmith. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 90s.

Nigerial Handbook of Commerce and Industry. Fourth edition. Compiled and Published by the Federal Ministry of Commerce and Industry, Lagos, Nigeria. Price 15s.

Vacuum Technology Transactions Proceedings of the Sixth National Symposium. Edited by C. Robert Meissner. Pergamon Press, Ltd., Headington Hill Hall, Oxford. Price 120s.

A Manual of Spherical and Practical Astronomy. Vol. 1. By William Chauvenet. Dover Publications, Inc., 180 Varick Street, New York, 14, New York. Price 2.75 dollars.

Hydrometry. Theory and Practice of Hydraulic Measurements. By Professor A. T. Troskolanskii. The Pergamon Press, Ltd., Headington Hill Hall, Oxford. Price 120s.

An Introductory Treatise on the Lunar Theory. By Ernest W. Brown. Dover Publications, Inc., 180, Varick Street, New York, 14, New York. Price 2.00 dollars.

Oscar Faber's Reinforced Concrete. New edition rewritten and extended. By John Faber and Frank Mead. E. and F. N. Spon, Ltd., 22, Henrietta Street, Strand, W.C.2. Price 75s.

The Modern Slide Rule. Third edition. By Richard Stender and K. K. McKelvey. Cleaver—Hume Press, Ltd., 31, Wright's Lane, Kensington, London, W.8. Price 6s.

The Physical Examination of Metals. Second edition. By B. Chalmers and A. G. Quarrell. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 168s.

Fluid Mechanics for Engineers. By Maurice L. Albertson, James R. Barton and Daryl B. Simons. Prentice-Hall International Inc., 28, Welbeck Street, London, W.1. Price 88s.

Kinetics Equilibria and Performance of High Temperature Systems. Edited by Gilbert S. Bahn and Edward E. Zukoski. Butterworths, 4 and 5, Bell Yard, London W.C.2. Price 80s.

The Continuous Casting of Steel in Commercial Use. By K. P. Korotkov, N. P. Maiorov, A. A. Skvortsov and A. D. Akimenko. The Pergamon Press, Ltd., Oxford Hill Hall, Oxford. Price 50s.

Electrical Engineers Exhibition

No. III—(*Concluded from page* 453, *March* 24, 1961)

The tenth Electrical Engineers Exhibition organised by Electrical Engineers (A.S.E.E.), Ltd., was held at Earls Court, London, last week. More than 470 *British electrical manufacturers and other organisations participated and some of their exhibits are described below.*

Brush Electrical Engineering Company, Ltd.

A 30 h.p. d.c. motor with special control by a static rectifier supply unit was exhibited (Fig. 13) by Brush Electrical Engineering Company, Ltd., Loughborough, and won the premier award for new industrial equipment shown at this exhibition.

A prototype (about 1 h.p.) which formed the basis of this system was demonstrated at last year's exhibition and was described in our issue of April 15, 1960, page 645. The present equipment for a 30 h.p. motor is shown in Fig. 13. Controlled silicon rectifiers are used to vary armature voltage, and are duplicated in the reverse direction for regenerative braking. They can also be used for reverse operation of the motor. An auxiliary rectifier supplies the machine field, and armature current is automatically limited to any level by a current limit circuit.

Control is provided by a closed-loop servo mechanism in which the speed signal from a tacho-generator is compared with a reference producing an error signal which feeds a transistorised control amplifier. A linear phase-shift circuit, controlled by the amplifier, supplies four pulse circuits which fire the rectifiers in a bi-phase rectifier-inverter power circuit. Both amplifier and pulse circuits are mounted on plug-in boards for ease of maintenance.

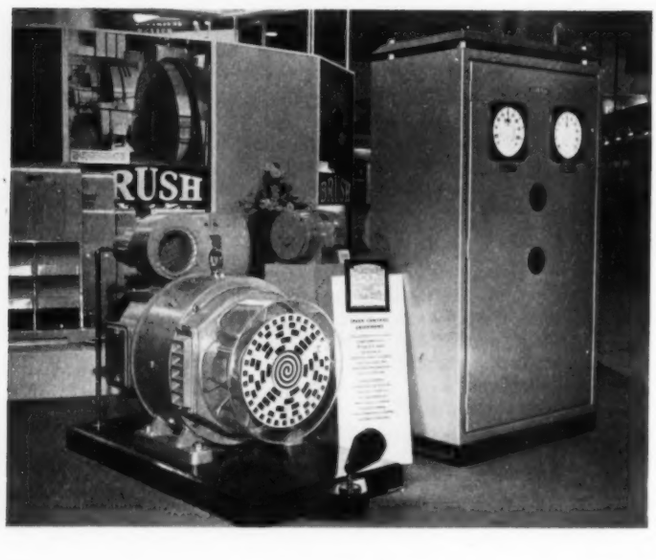


Fig. 13—30 h.p. motor controlled by static rectifier supply unit—Brush

Standard Telephones and Cables, Ltd.

A simple packaged supervisory system was shown by Standard Telephones and Cables, Ltd., Connaught House, Aldwych, London, W.C.2. It is to give remote control and indication in installations such as small unattended electricity distribution sub-stations, pumping stations, dam intake gates and other hydraulic works. It makes use of coded signalling and will work over two or four pilot cores or equivalent voice-frequency or radio channels. The system can give remote indication of the closing or opening of up to sixteen electrical contacts and can exercise remote control over any number of functions up to sixteen. Two-way telephonic communication can be maintained between the control station and the out station without prejudice to the operation of the signalling system. Check signals can be sent from the control station.

The control station unit weighs 155 lb. and measures 34in (plus 4in beacon) by 27in by 15in. The outstation unit weighs 180 lb and measures 34in by 27in by 15in. In each case the power supply unit weighs 70 lb and measures 150in by 10½in by 9½in.

A 500kW silicon rectifier equipment for use in d.c. substations was also shown. It is one of a pair rated for class-II duty to B.S. 1698 : 1960. They have a combined output current of 4450A at 225V in a maximum ambient temperature of 35 deg. Cent. and the design allows for a 25 per cent overload for two hours or a 100 per cent overload for fifteen seconds. These "SenTerCet" equipments, which are being provided to replace a rotary convertor in a steelworks, will supply 1MW of power for crane motors and other heavy current equipments.

Visitors also saw a recent addition to the range of "SenTerCet" equipments. It is a constant-current battery charger using silicon rectifiers and incorporating transductor control. This charger operates from 200V–250V, 50 c/s, single phase and gives an output sufficient to charge up to thirty-two lead acid cells at 30A.

D. Robinson and Co., Ltd.

Two sizes of new plug-in relays made by Clifford and Snell and fitted with built-in transistorised relays were shown by D. Robinson and Co., Ltd., 5-7, Church Road, Richmond, Surrey. These relays are designed to allow control by light-duty contacts, such as those found in manometers and contact thermometers, the power handled being 3mW or 1mA at 3V. The power supply required is 24V, d.c., with a maximum variation of 22V to 26V and a maximum ripple of 2 per cent ; the current consumption is 30mA. The external contacts used to switch the relay on and off are fed from the relay unit. A contact assembly of two changeovers is fitted ; the contacts can be either fine silver or silver-palladium.

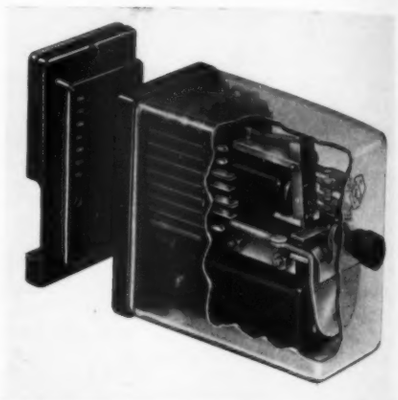


Fig. 14—Plug-in relays with built-in transistorised amplifiers—Robinson and Co.

The relay coil is connected in the collector lead of a p-n-p transistor with the base normally connected to emitter. Under these conditions the only current through the relay coil is the collector leakage current, about 50 microamperes. When the control contacts are closed a forward bias is applied to the base of the transistor sufficient to "bottom" it. Under these conditions the collector-to-emitter voltage falls to about half a volt and virtually the whole of the supply voltage is applied to the relay coil.

The two relays (designated D2600/T—Fig. 14—and D3400/T) have operating times of twenty-two milliseconds and eighteen milliseconds respectively ; both have release times of 150 to 200 milliseconds. The recommended temperature range is from 20 deg. to 80 deg. Fah. and the maximum permissible ambient temperature is 110 deg. Fah.

Another new exhibit on this stand was a "bonus clock" (made by the Rodene Electrical Company, Ltd.) which is designed to enable operatives working on bonus schemes to achieve higher output with less strain.

Electrical Research Association

Films illustrating the activities of the six research divisions into which the E.R.A's activities have been reorganised recently were shown by the Electrical Research Association, Cleeve Road, Leatherhead, Surrey.

Insulating Materials.—Some aspects of the work on the fundamental processes of breakdown in a liquid dielectric are well shown on ciné film. Breakdown of a liquid dielectric between a sharp point and a plane spaced a few millimetres apart originates locally at the electrode point as a result of electron emission. In mobile

Fig. 15—Formation of branching conducting channels from a point electrode in an insulating liquid—E.R.A.

liquids dissociation of liquid molecules under electron bombardment causes evolution of gas bubbles which move rapidly away from the region of high stress at the sharp point and the dissociation can be localised to this region. Under similar conditions in very viscous liquids, however, the decomposition products tend to remain in the region where they are formed ; if one of the products is carbon, then conducting channels may start and propagate from the sharp point towards the other electrode. Because they are conductive these channels tend to grow, the region of maximum stress, where local breakdown occurs, being transferred from the point to the end of the channel. Branching of the channels takes place. The rate of propagation can be made so slow that it is possible to study the breakdown process microscopically. A sequence of stills from the film is reproduced in Fig. 15. A direct study of the mechanism of breakdown is possible by this means.

Total or local breakdown of an insulating liquid can happen at low electric stresses in the presence of an impurity which is electrically unstable, such as a conducting bubble of gas or of another liquid. As the applied stress is progressively increased the bubble is elongated slowly in the direction of the electrostatic field until a critical shape is reached (the ratio of the diameters being 1:8) when the bubble becomes unstable. In mineral oil instability of the bubble leads to the formation of sharp points at the ends, where local disruption of the liquid can take place (Fig. 16.)

To facilitate a study of this breakdown process a rotating cell has been developed to contain the insulating liquid : rotation of the cell keeps the bubble in a central position so that the process of elongation and final disruption can be recorded on ciné film.

Switchgear and Transformers for Power Supply.—Another film shows the principles of arc extinction in—(1) oil circuit breakers, (2) air-blast circuit breakers, (3) arc chute circuit breakers, by making use of very small " Perspex " models. In (1) the contacts separate under oil within an enclosure, so designed that the heat of the arc decomposes some of the oil, liberating hydrogen and hydrocarbons. These gases are directed as a blast across the arc. This sonic blast of hydrogen cools and deionises the arc. In (2) the blast of gas, instead of being supplied by thermal decomposition of a liquid, is supplied from an air reservoir. In the model shown in the film, the air flows upwards along the axis of the arc. The throat and the upper (fixed) contact are electrically connected. Type (3) is used for the control of smaller powers than the oil- or air-blast circuit breakers. An arc is drawn between two contacts and is driven into a chute by a magnetic field. In the chute it is elongated, and cooled by close contact with splitter plates.

Non-Industrial Applications.—This film is concerned with some of the experiments which E.R.A. has carried out to determine the practical and economic possibilities of a novel system of glasshouse shading which relies on the absorptive capacity of thin liquid films instead of on dried paste or slatted blinds. Such films are distributed over the glasshouse roof by perforated pipes running along the ridge. They are supplied, by a centrifugal pump, from a storage tank, to which the liquid returns via the gutters. Control may be effected manually or automatically by a photocell.

Industrial Applications.—The E.R.A. has found that contactor wear is accurately related to the coulombs passing between the contacts during arcing. This is a new idea of very great importance, since the assessment of contact life under given conditions is now possible, and may well have a bearing on future standardisation. Seventeen materials have been studied for contact welding and have been arranged in order. Materials such as silver-cadmium oxide come out the best. Contact erosion has also been studied for a range of metals. Some of this work was shown in a colour film.

Permali, Ltd.

Two kinds of glass fibre materials were shown for the first time by Permali, Ltd., Bristol Road, Gloucester. One is exemplified by a wave-wound tube for arc control pots in circuit breakers ; this material is available in diameters up to 6ft and lengths normally up to 20ft. The other is extruded glass fibre rod in diameters of $\frac{1}{4}$in to $\frac{3}{4}$in in four colours ; exhibits made from this material included stay wire insulators and whip aerials.

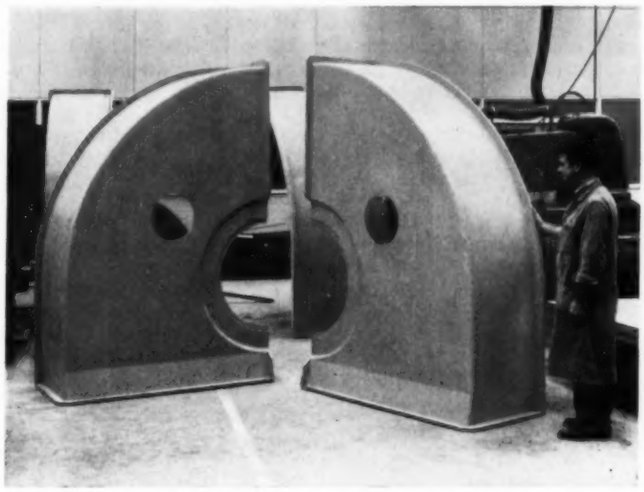


Fig. 17—Glass fibre end cover for large electrical machine—Permali

An interesting exhibit was a glass fibre end cover (Fig. 17), for a large electrical machine which is being made by the English Electric Company, Ltd.

Texas Instruments, Ltd.

Exhibits by Texas Instruments, Ltd., Manton Road, Bedford, represented circuit design using the company's industrial transistors and rectifiers. One of these with wide industrial possibilities was for the control of speed, without resistors, of d.c. motors in the range 0·1 h.p. to 5 h.p. The method can be compared with a vibrating voltage regulator except that no mechanical part is involved. The corresponding effect is obtained by varying the mark/space ratio of a Scarrotts oscillator driving a bank of Texas 2N456 series germanium alloy power transistors in parallel. The supply to the motor (a 24V, 1 h.p. series machine in the exhibition display) is connected via the transistor bank, which acts as a switch, being opened and closed at a high repetition frequency. Theoretically no power need be absorbed by the switch. The d.c. component of current in the motor is determined by

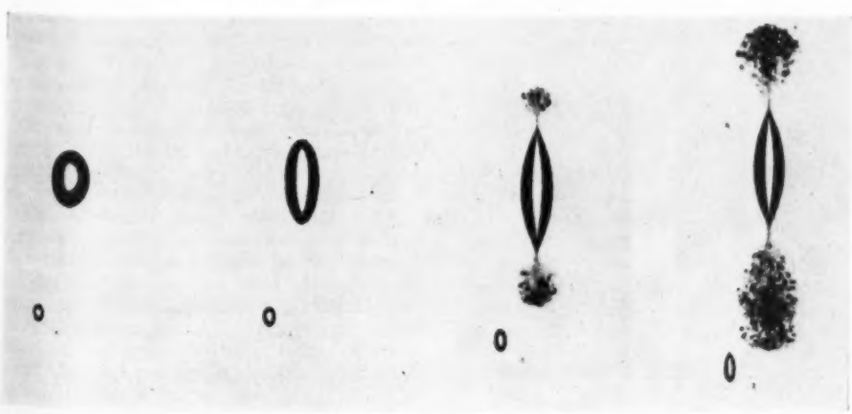


Fig. 16—Sequence shows elongation of a bubble, leading to breakdown of insulating liquid—E.R.A.

the switching mark/space ratio, and this is adjusted by means of a potentiometer which varies the constants of an RC circuit in the oscillator. A diode connected across the motor terminals forms a loop which maintains current during the " off " periods of the switch, so that voltage surges due to the inductance of the motor are eliminated. A range of control down to at least one-tenth full speed is obtained, and typical efficiencies throughout the range are stated to be 85 to 95 per cent. Suggested applications of the system are to vehicles such as fork-lift trucks, hoists, cranes and conveyor drives.

A further circuit shown was a low-cost bistable switching element using two silicon industrial transistors, and having an on/off impedance ratio greater than 10^7. The transistors are respectively p–n–p and n–p–n, and form the equivalent of a p–n–p–n device. At a certain level of input voltage to the circuit, a condition is reached where the sum of the current gains of the two transistors approaches unity. At this instant the transistors saturate due to regenerative feedback in the circuit, thus providing a low input impedance. This " on " condition is maintained provided the input current is held above the holding current. Applications include triggering silicon-controlled rectifiers, logic system bistable elements, and cross-point switching for telephone systems. The circuit was shown acting as a pulse generator in a traffic light control system (devised as a means of demonstrating several circuit elements). Here time intervals up to two minutes were produced by adjustment of a timing resistor, the associated capacitor remaining constant and being much smaller than would be necessary with a conventional multivibrator.

S.G.E. Signals, Ltd.

A conventional railway signalling track circuit detects the presence of a train within a certain length of track. The need sometimes arises for the arrival of a train at a particular point within the track circuit to be indicated, without interfering with any of the normal signalling functions. For this purpose high-frequency " overlay " track circuits are used. Such a circuit was demonstrated on the stand of S.G.E. Signals, Ltd., East Lane, Wembley, where it defined a position within a d.c. track circuit operating in the usual manner with a normally energised relay shunted by the presence of a train. The output from a 10 kc/s transistor oscillator was connected to one rail of the track, and a receiving circuit with a relay to the opposite point on the other rail. While there would in practice be a circuit from the oscillator to the relay via the rails and the apparatus at the feed and relay ends of the conventional track circuit, such a path attenuates the h.f. currents too much for operation of the " overlay " relay. When a train approaches, however, its wheels and axles provide an alternative path from rail to rail so that the relay picks up and remains energised until the train has passed. This occurs some 30ft before the train reaches the point at which the " overlay " circuits are connected to the rails, the impedance of the rails over this distance being low enough for the transfer of sufficient power from the oscillator to the receiving apparatus to operate the relay. This continues until the train is the same distance past the point of connection. Energisation of the relay can be maintained over greater distances by staggering the points of connection to the rails. The system differs from usual track circuiting practice in that the relay is normally de-energised, but the presence of a train is indicated by the signalling track circuit on which the " overlay " circuit is superimposed, and the functions controlled through the " overlay " relay would be such that failure to energise would not result in a dangerous condition.

Also displayed on this stand was a range of miniature plug-in signalling relays (Fig. 18) using a base which is being standardised by British Railways for all manufacturers. The base is suitable for various relay functions by wiring to the appropriate connections. Relays and plugboards occupy about one quarter the space of former standard sizes.

A display of road signals emphasised the export possibilities of this business by showing " Don't Cross " signals in a variety of languages and alphabets. The company's pedestrian-operated traffic signal controller is being redesigned with duplicate buttons and " wait " signs disposed for greater convenience of operation by pedestrians approaching the signal from either direction.

Mullard, Ltd.

Announcing a forthcoming range of industrial semiconductor power rectifiers, Mullard, Ltd., Mullard House, Torrington Place, W.C.1, showed a 20A, 200V, silicon double-diffused junction diode, BYZ14, which is the first in the series. This was demonstrated in a power rectifier cabinet designed by the Mullard Semiconductor Applications Laboratory which contained 168 of the diodes, providing an output of approximately 250kW. To meet the requirements of heavy electrical industry, although the rating for maximum recurrent P.I.V. is 200V, the permissible surge voltage (for ten milliseconds duration) is 400V, and every device is guaranteed to have a minimum breakdown voltage of 800V. Maximum average forward current is 200A, maximum recurrent peak 100A, and the permissible surge (for ten milliseconds duration) is 600 A. The diode is hermetically sealed and measures 62mm long (excluding lead) by 27mm. A threaded stud, 12mm diameter, allows a high spanner torque when mounting the device for good thermal contact with the heat sink, and the top lead is of braided copper wire more than $\frac{1}{4}$in thick.

Among three new Mullard cadmium sulphide photocells shown at the exhibition, the ORP50 (Fig. 19) has the distinctive feature of the sensitive tablet being at an angle of 45 deg. to the axis glass envelope, so that the cell may be illuminated end-on or side-on to allow flexibility in the mechanical design of equipment. The ORP50 cell is intended for use in flame failure detectors, and generally in industrial on-off switching applications. It has the advantage characteristic of cadmium sulphide devices that a sufficiently high current output is produced to drive a relay directly. From an illumination of five lumens per square foot, with lamp colour temperature 2700 deg. K, the cell will produce an average current of 10mA for an applied voltage of 20V. For the highest sensitivity requirements, a large-area cell, ORP30, has been introduced, which with 10V applied will produce 30mA from an illumination of five lumens per square foot at a lamp colour temperature of 2700 deg. K. The third new cadmium sulphide cell ORP93 provides a replacement for the Mullard 90CV and 90CG photo-emissive cells. The cell is suitable for a.c. or d.c. supplies and is sensitive to red and near infra-red radiation. Output at 10V is 6mA (average) in the conditions stated above.

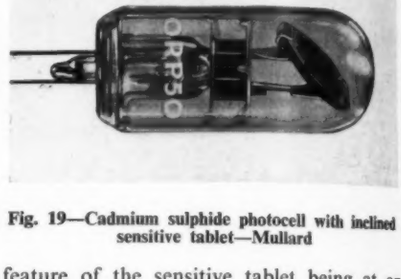


Fig. 19—Cadmium sulphide photocell with inclined sensitive tablet—Mullard

Westinghouse Brake and Signal Company, Ltd.

Further developments in the use of " Trinistor " controlled silicon rectifiers (The Engineer, May 29, 1959, page 854) were shown on the stand of the Westinghouse Brake and Signal Company, Ltd., 82, York Way, London, N.1. They included a pre-production prototype of a variable-speed d.c. motor control equipment for drives of up to 50 h.p. This is housed in a self-contained cubicle measuring 3ft 3in wide, 2ft 8in deep and 4ft 6in high for connection to any standard three-phase a.c. supply By varying the armature voltage a speed range of 20/1 is available with a constant torque characteristic. The speed range can be extended with field control.

The armature is fed by a three-phase full-wave bridge rectifier with silicon power diodes in three of the arms and " Trinistors " in the other three. " Trinistors " are the solid state equivalent of the gas triode and, therefore, the instant of commutation between rectifier arms can be controlled, and the power fed into the armature regulated. With fixed field, the armature back-e.m.f. is dependent on motor speed, and so may be used as a measure of it. A reference voltage equal to

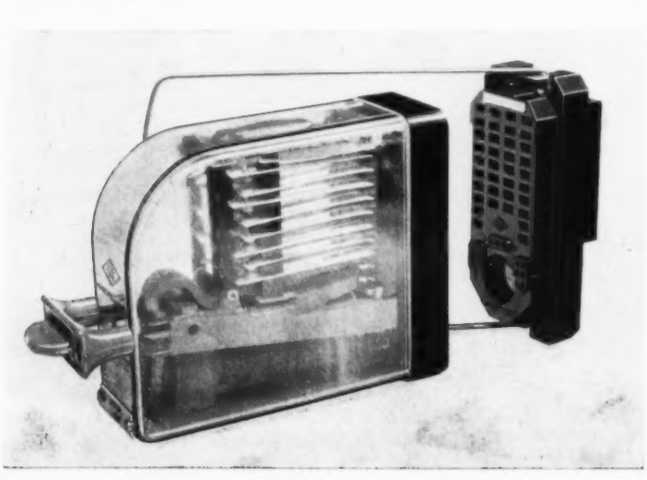


Fig. 18—Miniature plug-in signalling relay and standard base—S.G.E Signals

the back-e.m.f. at the selected speed is derived from the field supply and a feedback controller maintains the actual armature back-e.m.f. equal to this by varying the "Trinistor" firing angle. In practice, the terminal voltage is the one readily available; the back-e.m.f. is less than this because of the effect of load current on armature volt drop. This is compensated for in the controller, and results in a flat speed/torque characteristic over a wide speed range.

The controller also incorporates a current-limiting circuit which senses the incoming a.c. line current and delays the "Trinistor" firing angle if the corresponding d.c. current exceeds a given value. This automatically protects the rectifier from overload while allowing controlled motor acceleration free from current surges. Reversing, inching, crawling, dynamic braking and regenerated power absorption can be included if required. These facilities would normally be controlled by electromagnetic devices, but there are alternatives using only solid-state elements.

A further control scheme using "Trinistors" was demonstrated which provided regenerative braking and reversal of a 10 h.p. motor. In this system two oppositely-poled, three-phase bridges, each comprising six "Trinistors," function as controllable rectifiers for variation of motor speed, and as synchronous inverters to brake the machine by returning energy to the a.c. supply. A transistorised controller regulates speed by stabilising the armature voltage at any level and automatically limits acceleration and braking currents. Inverter applications demonstrated included a 1500VA inverter giving 115V, 400 c/s true sine wave, three-phase output from a 110V d.c. input for the operation of a.c. equipment from standby batteries in case of mains failure.

General Post Office

Reference was made in our March 17 issue to a paramatic amplifier to be shown by the General Post Office. This was a variable-capacitance diode instrument with a klystron as the source of pump frequency. This input is coupled by a probe into the resonant cavity of the device, which is resonant to the difference between the pump and the signal frequencies. There is a common input/output path for the signal via a ferrite circulator. The amplifier operates on 960 Mc/s and has been used in an experimental tropospheric scatter link, where satisfactory improvement in signal/noise ratio compared with other forms of amplification was obtained.

Layshaft Gear Cutting Line

The second automatic transfer line for machining gears on layshafts has been built by Churchill Gear Machines, Ltd., for the Austin Motor Company, Ltd. In its passage along this 200ft transfer line incorporating twenty-three machines all four gears are cut and finished on a layshaft. The line is designed to machine 4500 cluster gears per seventy-hour week when working at maximum output, one layshaft coming off every fifty-six seconds.

ABOUT two years ago Churchill Gear Machines, Ltd., of Blaydon-on-Tyne, supplied to the Austin Motor Company, Ltd., an automatic transfer line on which all four gears of a gearbox layshaft were cut. This line, described in detail in our issue of October 24, 1958, incorporated eighteen gear cutting and finishing machines, washing stations and gauging equipments, all being linked together by work transfer conveyors and using automatic loading and unloading devices. Recently the firm completed another of these automatic transfer lines to the requirements of the Austin Motor Company and this line, although generally the same, incorporated a number of improvements. We reproduce photographs showing some sections of the new installation when it was undergoing acceptance tests at the works of Charles Churchill and Co., Ltd., South Yardley, Birmingham. The new line includes twenty-three machines, as compared with the eighteen machines of the first line, and the gauging equipment previously used between the machine groups has been dispensed with. It is about 200ft long and is designed to machine 4500 cluster gears in a seventy-hour week when operating at maximum efficiency, one layshaft coming off the line every fifty-six seconds or at a rate of sixty-four pieces per hour.

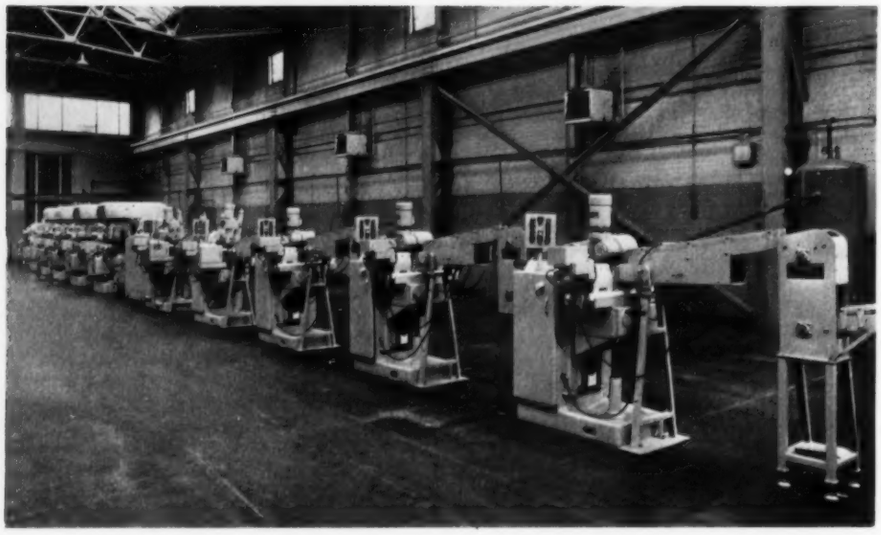
The machines are linked by the same type of standard conveyors with two designs—one for handling layshafts standing upright and the other for handling them in the horizontal position. The blanks are transferred between the line and the machines by "C.G.M." hydraulically-operated loading devices described in The Engineer of September 20, 1957. The layshafts are machined all over before entering the line and have a cone-centred hole at each end which is used for location purposes in all machining operations. At the head of the line a gauging equipment automatically checks all outside diameters to a tolerance of 0·005in before they are fed in for the gear cutting sequence.

To attain the required output, and provide for the varying cycle times on machines cutting the four different gears on a layshaft, different numbers of machines are engaged on each cutting operation. At each machine the conveyor system maintains a small bank of blanks and following blanks are deflected to subsequent machines. The line commences with a bank of eight Mark 4 Churchill "Rigidhobbers." The first three of these machines hob the fourth speed gears, the next three the third speed gears and the last two the first speed gears. The layshafts leaving the end of this bank are turned over on to horizontal guides along which they are rolled into a washing machine where they are cleaned by a high-pressure hot chemical spray which removes all cutting oil and adhering swarf. After being dried by subsequent air jets the layshafts are returned to a vertical position and picked up by the transfer conveyor.

The second speed gears are cut on the layshafts in the next bank of five "Fellows-England" high-speed gear shapers, supplied by Alfred Herbert, Ltd., of Coventry. After this operation the layshafts are again washed and passed through a group of three chamfering machines for the teeth of the second, third and fourth speed helical gears, followed by two tooth rounding machines for the first speed spur gears. In the chamfering machines the helical gears are meshed in backlash with a rotary cutter, the head of the machine moving to the right and left to remove acute edges on the gears. The ends of the spur gear teeth are finished by pencil-type cutters in the rounding machines.

Leaving the rounding machines the layshafts are washed and deburred by hand before being replaced on the line for finishing on a bank of four shaving machines where all four gears are shaved before final washing. In the line of chamfering, rounding and shaving machines the layshafts are transferred in a horizontal position and as an operation is completed each shaft is lowered

Bank of eight "Rigidhobber" hobbing machines for cutting the fourth, third and first speed gears on the layshaft



Transfer line of gear tooth chamfering and rounding machines. The four gear shaving machines can be seen in the background, left

on to a discharge chute which passes through the body of the machine. This discharge chute delivers the layshaft into an elevator on which it is raised and deposited into the end of a gravity feed chute leading to the next machine. Micro-switches on the chutes signal to appropriate machines to stop when the chutes are either full or empty.

After a final wash the outside diameters of the three helical gears are ground at one setting on a Norton cylindrical grinding machine using a formed wheel. At the conclusion of this final grinding operation the tolerances to which the layshaft gears have to comply are—eccentricity 0·002in ; profile ±0·0002in ; lead ± 0·0002in per inch face width ; and size ± 0·0005in.

The line is not controlled from a master panel, each machine and conveyor being started individually, and the whole line is thereafter controlled by switches operated in sequence by movement of components on the conveyor or the machines. Any one of the eight hobbing machines in the first bank of the line can be stopped for tool changing purposes without affecting the operation of the other machines. The eight machines are designed to " balance out " their production times and each can be operated for a period sufficient to enable a preceding machine to have its tool changed. The stipulated number of components cut between hob regrinds is 250. The shaping machine output is similarly balanced and the intended cutter life between regrinds is sufficient for the production of 100 gears.

Road Schemes in and around London

SEVERAL new road schemes have recently been announced by the Ministry of Transport and the L.C.C., and the latter's proposals for the South Bank, although not primarily a road scheme, include road improvements.

Buckinghamshire Motorway.—The Minister of Transport, has advertised the proposed line of a 13½ mile motorway in Buckinghamshire, which is expected to cost some £7,000,000, and will supersede the congested part of the London–Oxford trunk road (A.40) in the neighbourhood of Beaconsfield and the Wycombes.

From a point near the junction of A.40 with Burkes Road at Beaconsfield, the line proposed for the new road runs in a general north-westerly direction through open country south of High Wycombe to Stokenchurch, where it rejoins A.40 west of its junction with Mill Road. In addition to by-passing High Wycombe and Stokenchurch, the road would relieve A.40 of its through traffic in the built-up areas of Loudwater, Wycombe Marsh, Chepping Wycombe and West Wycombe.

It is planned to have two 36ft carriageways for the five-mile stretch from the eastern terminal of the motorway at Beaconsfield to a two-level junction with A.404 (the Marlow road) at Handy Cross. From this junction to another at Stokenchurch, where the new road rejoins A.40, two 24ft carriageways are projected. A viaduct will be necessary to carry the motorway over the River Wye, Station Road and the railway line at Loudwater. Objections to the proposed route may be lodged during the next three months.

Kingston By-Pass Flyover.—The Minister of Transport, has also approved the construction of a flyover where Kingston By-pass is crossed by Burlington Road and joined by Bushey Road. The cost with associated improvements is estimated at £1,300,000.

Over 4000 vehicles an hour pass through the existing Burlington Road junction during the morning and evening traffic peaks. Under the new plan, through traffic on the by-pass will be carried over the junction on a flyover with dual three-lane carriageways and built on a one-in-twenty-five gradient. Traffic joining or leaving the by-pass at Burlington Road will use slip roads, each with two lane carriageways, and a ground-level roundabout.

At the Bushey Road junction where traffic in the evening builds up to 3300 vehicles an hour, drivers coming from the south and turning off the by-pass into Bushey Road now cut across the main traffic stream from London. When the new junction is built, this turning traffic will weave to the left after passing Burlington Road then rise on a gradient of one-in-twenty-five to pass in a curve over the by-pass, descending on a gradient of one-in-thirty into the existing Bushey Road.

The designer of the flyover is the Surrey County Council's county engineer, Mr. D. S. Samuel, M.I.C.E. With the widening of Carters Bridge over the Southern Region Railway, the double flyover will be the principal engineering feature of the modernisation of Kingston By-pass from the Burlington Road junction to Robin Hood Gate. When completed there will be dual three-lane carriageways on the by-pass for more than 6 miles.

Flyover Proposal at Bow Bridge.—The L.C.C.'s roads committee has offered a scheme for an improvement at Bow Bridge, which crosses the county boundary on the River Lea. When the Blackwall tunnel is duplicated, there will be increased traffic in this area, but there seems no doubt, the L.C.C. states, that the through traffic using Bow Road and Stratford High Street will still be the heaviest stream. This traffic will accordingly be taken on a flyover, and a roundabout will be provided for north/south and ferry traffic.

The roundabout will be partly over the River Lea and it will be necessary to put in a temporary bridge during the course of the work and demolish the present bridge. Care will be taken to ensure that the western approach to the flyover will not cause disturbance to the structure of Bow Church which, although restored, still retains some fourteenth and fifteenth century work. To help deal with the increased Blackwall Tunnel traffic, Old Ford Road is to be realigned and widened for about a quarter of a mile. It is hoped to start work in 1964, and the cost of the scheme will probably be of the order of £1,500,000, although detailed estimates have not yet been prepared.

Reconstruction of river wall Millbank.—Work will start soon on the widening of Millbank between Atterbury Street and Thorney Street, to a width of 90ft, taking six lanes of traffic. It will be necessary to reconstruct part of the river wall further out into the river. The project has been approved by the Minister of Transport for inclusion in the L.C.C.'s priority programme of major road improvements. The estimated total cost is £509,350.

South Bank Development.—The L.C.C. has also sponsored a scheme costing £3,704,000 for development of the South Bank from the Royal Festival Hall to Waterloo Bridge. Completion of the Festival Hall, and provision of a small hall, and an exhibition hall are the main points. There will, however, be new loop roads giving access to the area, and an underground car park for 170 cars. There will be a continuous promenade through the area.

What is noteworthy is that the fundamental design approach to the scheme is based upon the need to segregate motor vehicle and pedestrian traffic. This is achieved by two pedestrian systems from Waterloo Station. The one in principal use will link all the building elements and provide a through circulation at high level between Waterloo Bridge, Hungerford footbridge and Waterloo Station without contact with vehicular traffic ; the second pedestrian system will link Waterloo Station and the proposed low level pedestrian system under a new traffic roundabout at the southern approach to Waterloo Bridge thence on the downstream side of the Bridge toward the river front. These two systems will be linked at a number of points.

The vehicular circulation takes the form of two one-way loops from Belvedere Road. The downstream loop road passes between and serves the new concert hall, the Exhibition gallery and the repositioned entrance to the National Film Theatre, returning to Belvedere Road on the downstream side of Waterloo Bridge.

The car park for 170 vehicles is to be sited below the Exhibition gallery and is accessible from this road. The upstream loop road passes in front of the riverside facade of the Festival Hall and under Hungerford Bridge, returning to Belvedere Road on the upstream side of Hungerford Viaduct. A car park arranged in two tiers below a pedestrian podium, will be provided at a later date for 550 cars in this area.

ROAD TUNNEL SCHEME IN HONG KONG.—Construction of a mile-long road tunnel through the Kowloon hills in Hong Kong is to be started. The tunnel will take two years to complete, it is stated, and will cost about £343,750. It will accommodate a 24ft carriageway, and three or four large water mains.

Wool Research Association

THE opening by Mr. R. G. Menzies, the Prime Minister of Australia, of the new worsted processing block at the Wool Industries Research Association, Torridon, Leeds, on Wednesday, March 22, marked another stage in the advancement of the work of the Association. It was in 1915 that the initial steps were taken to inaugurate a research committee representative of the wool textile industry, and in 1918 a co-operative industrial research association was set up with the support of D.S.I.R. and named "The British Research Association for the Woollen and Worsted Industries." The present name was adopted in 1930. The Torridon estate was acquired in 1920 and since that date various extensions have been made and new buildings added including a chemistry section in 1927, the acquisition of an adjoining estate in 1928, and a wet processing block in 1939. After the war further expansion of research facilities was planned and a progressive building scheme commenced which has resulted in the addition of the Physics, Weaving and Woollen blocks in 1952 and the recent completion of the Worsted Block. Work at Torridon is essentially practical and is concerned with the application of science and technology to a craft industry.

The worsted section of the wool industry had a consumption of 400 million pounds of clean wool together with 20,000,000 pounds of man-made fibres in 1959, and the new block is equipped with facilities for research into various worsted processes such as scouring, carding, combing, drawing and spinning. All these pose problems which are of fundamental and practical importance to the industry so that the opening of the new block now enables research work, which has hitherto been restricted in scope due to lack of accommodation, to be put in hand, under Dr. A. B. D. Cassie, the Association's Director of Research, to give a better service for the industry. The steel framed new building, which is fire resisting throughout and has floors of reinforced concrete to permit interchangeability of machinery, has three floors and a basement having a total area of 41,000 square feet. A heating installation and humidifying plant enable conditions to be adjusted to suit the requirements of the various processes, while light-diffusing glass bricks have been used instead of windows in the south elevation so as to avoid direct light which is undesirable for textile processing.

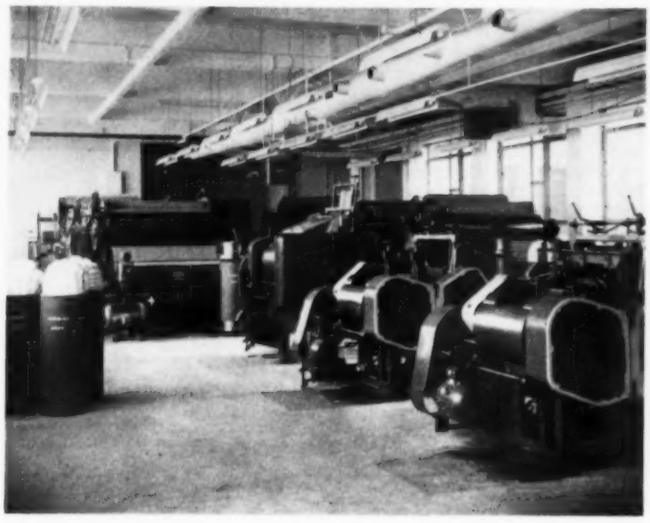
Fibre breakage, which occurs during carding, is often excessive and is due largely to the degree of entanglement of the scoured wool fed to the card. Thus the scouring process is of fundamental importance and to assist in the study of the mechanics of wool scouring a pilot-scale plant, illustrated herewith, rated to process 300 lb of greasy wool per hour, has been installed. It consists of a four bowl set and a single lattice warm air dryer and also a meter pump and pipe system to add controlled quantities of soap and alkali, and is designed to improve the traditional methods of scouring and to study the use of detergents. In the carding and combing area, part of which can be seen in our illustration, there are two 60in wide cards, one representing the Bradford and the other, the Continental Systems in which the wool is opened out, mixed and cleaned to produce card sliver. Further mixing takes place in another machine in which five card slivers are mixed to give greater uniformity. A Schlumberger French comb and also a Noble comb are fitted, and the latter is the subject of study with the object of improving both uniformity and output. Investigations include the problem of the short life of comb leathers, and with this in view the drawing-off rollers have been redesigned. Other studies relate to the incidence of "burrs and reps" and to increasing the proportion of "top" (long fibres) to "noil" (short fibres). Improvements in this direction have raised the rates of tops to noils from 9 to 1 to 12 to 1. The sliver from the Noble comb is subjected to further levelling in an Autoleveller first finisher and an intersector top finisher in preparation for spinning.

Much of the research programme is concerned with the improving of machinery techniques, so that the new building provides space for comparative tests to be carried out using different machines and using various categories of wools. This work is of particular importance in the drawing and spinning processes, since they employ the largest proportion of labour, and the aim is to increase productivity combined with the reduction in yarn irregularity. Production machines installed include the Bradford system, the Raper-Bradford system and the Continental system, and among this drawing machinery are the W.I.R.A. rotating can system and a high-speed gill box. In the spinning section are a cap spinner, a cap spinner converted to an Ambler superdraft spinner which enables the number of stages of drawing to be reduced, a cap twister, a ring twister and a winding frame.

Provision is made for carrying out trials on new processing machines to establish performance characteristics and to demonstrate plant, and also to be available for direct consultation with members.

The Association has been responsible for the development of various devices as a result of research into many of the industry's operations. Among these can be mentioned the Full-Width Temple which reduces tension in the warp at beat-up and so minimises the number of breakages and the Dropper Pinning Machine in which the dropper detects when the warp end breaks and stops the loom. The machine improves the efficiency of the preparatory processes. Other equipment includes: a cop grading machine; the roving levelness tester; the Autocount; and the rapid oil extraction apparatus for mill control.

Pilot plant for scouring of raw wool



Carding engines with gill boxes in foreground

Technical Reports

Specification Notes for Structural Reinforced Concrete in Buildings. Reinforced Concrete Association, 94-98, Petty France, London, S.W.1.—This publication has been prepared as the outcome of the frequent requests received by the Joint Committee on Structural Concrete from architects for draught specification clauses for reinforced concrete constructional work in buildings. An attempt to meet this need has been made by giving clauses based upon the recommendations of the British Standard Code of Practice C.P.114, 1957. In presenting the clauses a number of explanatory notes have been included for the general guidance of architects and engineers.

Design of Air Bearings and their Application to Measuring Instruments and Machine Tools. By H. L. Wunsch, M.Eng., A.M.I.Mech.E. N.E.L. Report Mech/Met 145. National Engineering Laboratory, East Kilbride, Glasgow.—This report concerns work carried out on externally pressurised air bearings. The first part contains a description of an investigation of a flat pad bearing, which was carried out to determine its behaviour under static load conditions for a variety of design parameters. The results of this work have been expressed as a series of empirical design formulae relating lift, stiffness and load for the design parameters used. Further tests on a similar bearing under dynamic load conditions are also described and some typical results are given. The second part of the report deals with applications of air bearings with particular reference to machine tool slideways. The results obtained from the experimental investigation are applied to the design of a milling machine slideway, as well as to several measuring instruments employing air lubricated bearings.

A New Portable Vacuum Manometer. By A. T. J. Hayward. N.E.L. Fluids Note No. 85. National Engineering Laboratory, East Kilbride, Glasgow.—The conventional mercury manometer commonly takes the form of a "U"-tube, sealed at one end, of constant-section glass tubing, calibrated to indicate pressures from zero to 300mm Hg absolute. Some, though not, the report stresses, all of the errors of such instruments are due to the presence of air in the Torricellian vacuum above the mercury, and errors due to this cause will be particularly large when the vacuum is small in volume, i.e. at the high-pressure end of the scale. For portable instruments where to lengthen the scale is undesirable, it is therefore proposed to expand the closed end of the tube into a bulb immediately above the scale. To prevent the free surface becoming inverted when the mercury is drawn into this bulb, a similar bulb is included in the opposite leg of the "U"-tube just above the bottom.

SHORTER REPORTS

Rural Electrification in the West Country

PLANS to bring electricity to 10,000 more rural properties (including more than 3000 farms) in the West Country by March, 1963, were announced last week to the South Western Electricity Consultative Council which is responsible for protecting the interests of over 750,000 consumers.

In the programme for 1961–62 it is planned to make electricity available to 5500 rural consumers, including more than 1600 farms, mainly in Devon, Somerset, and Cornwall. The tentative programme for 1962–63 provides for the connection of nearly 5000 rural consumers including just over 1400 farms.

Although the Electricity Board is increasing its annual expenditure and is achieving a high rate of rural electrification the council was warned by the Board that "many people (without electricity) inevitably will be disappointed, as in March, 1963, there will still be 7000 farms and several thousand more rural properties still awaiting supply." This was a big task and it would take many years to complete. Provided the capital was available, plans had been made to connect 85 per cent of all farms by the end of 1964. This would then leave about 4500 farms and less than 10,000 other rural properties to be connected.

Irradiation Services in "Jason" Reactor

IRRADIATION services in the "Jason" reactor at the works of the Hawker Siddeley Nuclear Power Company, Langley, Bucks, are now available to outside organisations. These services are additional to the training courses already provided on the reactor. Apart from producing irradiated material, these services can also be used for activation analysis—a more accurate method than ordinary chemical analysis for measuring small quantities of materials in chemical compounds—and for neutron diffraction methods to investigate the structure of solid materials.

Factories and medical organisations in the London area should find these services of particular value, since radioactive materials suffer losses in strength depending on delivery time from reactor to laboratory. Therefore, under certain circumstances, a "local" reactor of "Jason's" capabilities can often deliver more strongly radioactive material than a much more powerful reactor on a remote site, and this advantage is specially important when medium and short-lived isotopes are needed. "Jason" can operate at a flux of 10^{12}n per square centimetre per second

Modernisation of the Trent Navigation

BRITISH WATERWAYS has nearly completed its modernisation scheme on the River Trent Navigation, and by the end of this year over £400,000 will have been spent, out of an estimated £473,000 for the whole scheme, which extends between Nottingham and Cromwell. In addition to this expenditure, the reconstruction of Cromwell Weir was completed two years ago at a cost of £270,000; and other works on the waterway have included a new lock at Newark opened in 1952, a repair yard and dry dock at Newark, and improvements at depots at Nottingham. This development work matches the traffic potentiality of the Trent Navigation, which is one of British Waterways' most promising broad waterways, and one on which traffic is increasing; craft 140ft long and with a beam of 18ft 6in navigate up to Trent Bridge, Nottingham.

Work up to the end of this year on the development scheme is divided as follows: £81,700, bank protection in steel and concrete sheet piling; £75,500, steel piling and concreting to consolidate the main river weirs; £51,700, mechanisation of locks; £163,400, dredging plant and equipment; £39,100, extension of Cromwell lock; £2400, repair yard plant. One of the principal features of the scheme is the mechanisation of seven main locks which will reduce locking time by about half. Already the locks at Newark Town and Cromwell have been mechanised, and two more—Newark Nether, and Gunthorpe—are nearing completion. It is hoped to start work on the remaining three —Hazleford, Stoke, and Holme—later this year or early in 1962.

Cromwell lock, at the limit of the Trent's tidal influence some 5 miles downstream from Newark, has been extended and mechanised at a cost of £57,600. It can now accommodate eight standard Trent barges, or three large oil tankers, and pass them through in one "locking" operation. Hitherto the lock could only handle four standard craft or one large tanker, and was not sufficiently deep to pass them through at all states of the tide. Now, even when the downstream water is below normal, the extended lock can pass through two large tankers at a time.

Mechanisation of the locks has been carried out by Stein Atkinson Vickers Hydraulics, Ltd., and consisted, in the first instance at Cromwell Lock, of double acting cylinders for the operation of the sluices and gates, each being individually controlled by a four-way manual valve situated at one central position, thus enabling the lock-keeper to control the entire sequence of operation of the lock from the same vantage point. Power is provided by a double pump mounted above the reservoir, each pump supplying oil at 1000 lb per square inch to one side of the lock only, to ensure that pairs of gates or sluices can be moved in unison as well as individually. The natural tendency of the sluice is to close and, therefore, check valves are used to retain the sluices in the raised open position, necessitating positive pressure to close the sluice and, hence, a positive action by the lock-keeper.

Sluices and gates can, at will, be stopped at any instant, and a system of relief valves enables the gates to yield without damage to the hydraulic system, should the gates be rammed by a barge when the water level is the same on both sides of the gate. The individual four-way valves are arranged as double valves, interconnected in such a manner that, when all the spring centred control levers are released, a by-pass opens to the reservoir, conserving power and preventing overheating of the hydraulic installation.

This installation proved successful, but from the experience gained it was obvious that for the larger installations, larger bore pipes would be required to prevent too high a pressure drop in the respective pipelines between the four-way directional control valves and the cylinders, caused by a high oil viscosity when operating at temperatures of about freezing point. It was, therefore, decided that the next installation at Newark Town lock should be constructed using the ring main principle to reduce the installation piping cost.

This principle embodies two pumping units, each being situated at the approximate mid-position on either side of the lock. A single vane pump, having a capacity of 5 g.p.m. at 1500 lb per square inch and driven by a 7½ h.p. electric motor, supplies oil through a pipeline to the extreme ends of the lock side, returning to the pumping unit. A recirculating ring of hydraulic power is, therefore, available on each side of the lock, enabling a limited amount of heat to be added to improve the viscosity of the oil in cold weather. Pilot-operated four-way valves are connected into the ring main adjacent to the respective gate and sluice cylinder, the four-way valves being remotely operated by spring centred hand control valves situated at one central position. To conserve power, the handle control valves are arranged so that when the lock is idle, with all hand levers spring centred, the oil in the ring main circulates at the low pressure required to maintain the flow of oil. This ring main provides the same type of safeguards as already described.

The mechanisation has enabled gates on the 22ft wide locks to be opened and closed in approximately twenty seconds, and the gates on the 30ft wide locks in thirty seconds. Sluices are generally opened and closed in approximately ten seconds.

Fluorescent Lamp Tubes of Increased Efficiency

THE use of two new manufacturing processes has increased the efficiency of the 8ft, 125W, "Warm White" and "White" fluorescent tubes made by the "Osram" Lamp Division of The General Electric Company, Ltd., of England. A light output of 9000 lumens for the first 100 hours and an average of 8250 lumens throughout subsequent life is claimed for these lamps: these figures are believed to be the highest for any tubes made in Europe.

Two "Osram" processes are responsible for the improved performance. The first is a system whereby the powder can be classified into particle sizes, only the particles with the greatest efficiency being selected for use. The second is a new water-soluble-binder process which places these selected particles on the tube in such a way as to obtain maximum conversion of ultra-violet energy into visible light Both tubes are fitted with BC Bi-pin or RDC caps and can be used in any installation using 8ft 125W tubes. As they operate on a standard circuit and in single, twin or multi-type fittings, it is not necessary to modify either fittings or circuit.

The "White" tube should prove most useful where a high efficiency is important. Its colour lies between that of "Warm White" and "Daylight" and it is particularly suitable for industrial applications and some shop or office installations. The "Warm White" tube is especially suitable for commercial premises, offices, factories and street lighting.

Under the maker's guarantee a free replacement will be provided if a tube fails in normal service before 300 hours or one year of use. This guarantee covers all straight "Osram" tubes listed in the range 9in 6W to 8ft 125W.

Superfine Wirecloth for Filters

A SUPERFINE filter medium primarily developed for precision hydraulic and fuel systems in the aircraft and rocket industry is now being woven commercially for the first time in this country by the United Wire Works, Ltd., Edinburgh. This 325/2300 mesh Micro-Hollander stainless steel wirecloth has a high degree of uniformity and is stated to retain particles of the order of 10 microns (·00039in). A square inch of cloth comprises 325 warp wires running lengthwise, interwoven with 2300 tightly knocked up weft wires. Being twill woven the individual wires in one direction pass alternately over two and under the next two cross wires in succession. This provides 747,500 openings per square inch.

Unlike square woven wirecloths the openings in this hollander specification are not apertures in the true sense of the word. Although uniform in critical dimension they follow a sinuous path through the thickness of the cloth, do not permit transmission of light, and penetration of liquids is only possible under pressure. The material offers many advantages over other filter media, not least being the accuracy and regularity of limiting opening size. Its robust structure permits high working pressures, while it has excellent corrosion resisting properties and its application can cover a wide temperature range.

Chemical Pump

A VARIABLE delivery diaphragm pump for chemicals introduced by Diafilter Engineering Company, Ltd., 902, Purley Way, Purley, Surrey, is capable of delivering from 2·0 to 20 gallons per twenty-four hours against pressures

Variable delivery chemical pump with output adjustable between 2 and 20 gallons per 24 hours

up to 100 lb per square inch without the need for a balancing water supply. All of the parts in contact with chemical solutions are of special materials designed to resist the action of acids and alkalis. These components are enclosed within the head of the pump which is of clear plastic so that the pumping action can be observed.

The glass-fibre reinforced polyester body houses a fan-cooled motor of 60W consumption which is available for 200V/250V or 110V supplies. These pumps, one of which is illustrated above, weigh only 8 lb and are 10in long by 8in high. Each pump is supplied complete with suction and delivery tubing, point of application fitting, solution strainer assembly, cable and power supply plug.

[Reply Card No. E5251]

Automatic Reset Timer

SEVERAL functions normally requiring additional instruments are combined in the PT5 automatic reset timer introduced by Venner, Ltd., Kingston By-Pass, New Malden, Surrey. The synchronous timing motor and operating

Multi-purpose synchronous motor timer with automatic reset

contacts are brought out to separate terminals arranged in a semi-circle on a multi-way terminal block at the end of the cylindrical casing. By making the appropriate connections to this terminal block, the timer may be used with equal facility as a delay relay, re-cycling process controller, or single-operation process timer. A pair of contacts which close momentarily at the end of the cycle may be connected to a second timer, thus initiating its operation and allowing a group of timers to be interconnected for controlling a number of processes in a preset sequence.

The timing dial, 5in square, is of black anodised aluminium with white lettering, and has a bright anodised bezel. Time setting is effected by turning a moulded finger-grip knob, seen in the centre of the dial in the illustration, until the pointer shows the desired period. The centre disc also moves so that its arrow points to the same figure. This disc revolves when the timer is running, indicating the unexpired time, and returns to the set time position upon completion of the operation. All contacts on the PT5 timer are rated at 10A up to 250V or 5A up to 500V a.c., and the timer is available for operation on the usual commercial supply voltages and frequencies.

[Reply Card No. E5252]

Precision Horizontal Boring Machine

A NEW model of the "Optimetric" horizontal boring machine, which has been introduced by H. W. Kearns and Co., Ltd., Broadheath, Manchester, is to be exhibited at the Tokyo Trade Fair in April next. This 3in spindle machine for toolroom or general workshop use has a facing chuck covering up to 24in diameter and the maximum distance from the facing slide to the boring stay is 5ft. It can be seen in the photograph we reproduce on this page.

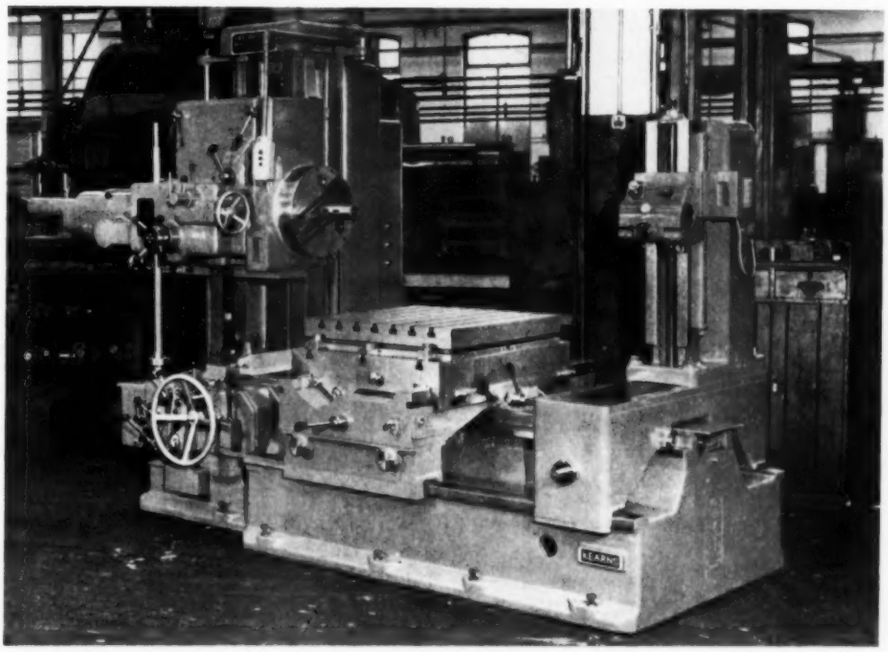
The main bed of cellular construction incorporates a central channel directly under the centre line of the travelling spindle and this channel, filled with lubricant, houses the longitudinal screw and shaft with their associated mechanisms. This means of submerging these parts and the centre bed using an oil bath ensures ease of operation, freedom from slip-stick and the minimum loading of the feed mechanism. The centre guide of the saddle slides in the bed channel and the outer ends of the saddle are carried on large rollers rotating on anti-friction bearings and supported on outer bed ways. The tables are fully supported in their extreme transverse positions and a 2ft 6in square revolving table is provided.

Under the maker's unit construction system each unit has an individual and automatic lubrication system. The gear and feed boxes are fitted with internal gear tooth clutches. The main 7½ h.p. motor is positioned to reduce to a minimum the transfer of heat or vibration to the machine. It drives a nine-speed gearbox through belting and a belt drive is used between the gearbox and spindle slide. The spindle slide has three gear changes giving, with the nine speeds of the main gearbox, a total of twenty-seven speeds to the machine.

The combination of the travelling spindle with a built-in automatic facing chuck makes the machine particularly versatile. A nitrided cast iron bush rotating in precision bearings supports the travelling spindle at its forward end, and the automatic facing chuck is carried on a large diameter sleeve mounted in two long phosphor bronze bearings. Only three simple components are used in the firm's new design of feed mechanism for the facing slide—a large concentrically mounted worm wheel drives two spiral gears working directly into two racks attached to the slide. This design enables the full power of the driving motor to be absorbed on surfacing operations.

Accurate and simple co-ordinate setting with the "Optimetric" system incorporated in the machine enables settings to be made to 0·01mm within 0·005mm. This system is provided for the vertical adjustment of the spindle slide and boring stay bearing and the transverse movement of the table.

[Reply Card No. E5253]



"Optimetric" horizontal boring machine

County Technical Library Service

LAST month the Hertfordshire Technical Library and Information Service was inaugurated by Sir Norman Kipping, J.P., at a ceremony in the Headquarters Library at Hatfield Technical College. This service is unique among the recently started schemes for supplying information to industry on a local basis, in that it is run by the libraries of the technical colleges under the aegis of the County Library. This gives it the advantage over schemes based on public libraries that technically trained members of the teaching staffs of the colleges are available to give assistance with the answering of inquiries. Firms in the county which subscribe, in addition to being able to make inquiries on technical subjects, can arrange to be supplied with a regular card service of information on subjects of interest to them, covering books, pamphlets and periodical articles received in the libraries. The colleges are building up a comprehensive collection of trade catalogues, and a trade name index. The service has also done pioneer work on the use of microcopies, and a well-equipped document reproduction laboratory is available. The service has been organised by the County Technical Librarian, Mr. G. H. Wright, F.L.A.

SHORTER REPORTS *(continued)*

Punched Tape Control System with Protective Device

THERE was recently demonstrated at the works of E.M.I. Electronics, Ltd., Hayes, Middlesex, a Droop and Rein vertical milling machine equipped with the "Emicon" punched tape control system incorporating what is termed a "safety angle unit." This safety device has been developed to check continuously the information derived from the tape whilst machining is in progress. It can be incorporated in any E.M.I. controlled contour cutting machines which have the facility for compensating for a cutter of different size from that for which the programme tape was made, the built-in computer controlling the machine supplying the control information. The device, having continuous access to the computer output before it actually controls the machining operation, detects an error in the tape in checking and stops the machine before a mistake is made and the work scrapped.

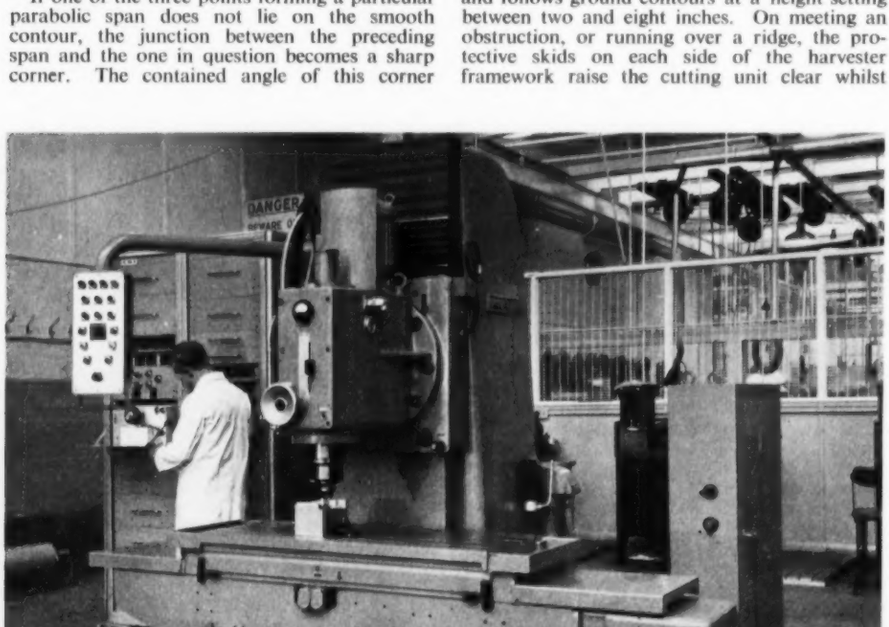
The "Emicon" system fitted to the machine demonstrated gives continuous contour control in any two axes with fine stop control and controlled feed speed in the third direction. The system provides for adjusting to zero in the three machining axes to facilitate and speed work setting and the input programme can be corrected to compensate for changes in cutter size resulting from sharpening which may be necessary during an actual machining operation.

With regard to the safety angle unit, in the E.M.I. control system the co-ordinates of suitable points on the contour to be cut are considered by the programmer in groups of three consecutive points. These groups, known as spans, do not overlap but have common end points, and the equipment interpolates a smooth parabola passing through each group of three points calculated by the programmer. Many contours are smooth throughout and consecutive parabolic spans are arranged by the programmer to blend tangentially into each other.

If one of the three points forming a particular parabolic span does not lie on the smooth contour, the junction between the preceding span and the one in question becomes a sharp corner. The contained angle of this corner depends on the degree of offset of the point which is not on the contour and which, therefore, is causing the corner. The equipment incorporates a rotary device called a resolver having a shaft the angle of which continuously indicates the angle of the surface of the contour at the point being cut. This indication is effected by "sampling" the commanded displacement of each axis over a very short length of time. Samples are continuously taken of how much the machine has just been instructed to move and the amount of the succeeding movement. If the angle changes suddenly by more than a preset amount due to an offset point, the advance information sample immediately detects the transient and trips the safety circuits to stop the machine. In preparing tapes for work involving sharp corners the programmer inserts a "corner" code in the programme at that point to inhibit the safety unit.

The Droop and Rein machine fitted with the tape control equipment is illustrated on this page and is of standard design specially arranged for tape control. Its 65in by 21in table has a longitudinal travel of just under 39½in with a transverse travel across the bed of 17in, and the vertical headstock travel is 19½in. The eighteen spindle speeds available range from 33 to 1750 r.p.m.

[Reply Card No. E5261]



Vertical milling machine with tape control system incorporating a device for anticipating an irregularity or error in the tape and automatically stopping the machine

Offset Harvester

A NEW offset forage harvester in which the tractor drivers' comfort and economy of effort have been the designers' main consideration has been introduced by David Brown Tractors Ltd. Controls have been placed within easy reach and can be adjusted to suit any make of tractor, whilst from the tractor seat, the driver is able to see clearly the full cycle of harvesting operations, including trailer coupling, cutting, loading and tipping.

The free-floating cutter unit is located on a hinged mounting to the rear of the drawbar and follows ground contours at a height setting between two and eight inches. On meeting an obstruction, or running over a ridge, the protective skids on each side of the harvester framework raise the cutting unit clear whilst the harvester land wheels remain in contact with the ground. Thus, only the weight of the cutter unit, which is approximately half the weight of the harvester, is borne by the skids. On particularly soft ground or for transport purposes the cutting unit can be raised well clear of the ground by means of the hydraulics. The cutting unit is driven from the tractor power take-off, the drive being transmitted through a spiral bevel gear-box and four V-belts. The drive and the rotor speed can be varied by changing the driving and driven pulleys.

David Brown "Hurricane" offset harvester

The harvester is equipped with a semi-automatic mechanism enabling it to be converted from the offset cutting position to the in-line transport position. When offset, the overall width of the unit is 9ft 11½in, whilst in the in-line position it is 7ft 10in. To effect the changeover the tractor driver pulls a trip-rope whilst the machine is moving forward. This releases a locking catch on the trackrod of the harvester, and the continuing forward movement of the tractor causes the harvester wheels to follow a castor-action which brings the harvester and trailer from the offset to the in-line position. To place the unit in the offset working position, tractor and harvester are backed and the trip-rope pulled, which results in the trackrod of the harvester being locked in the offset position.

A protected pivot mounting located inside the chute ensures free movement of the chute. The control lever for swivelling the chute and the deflector hood control can be adjusted to suit all types of tractors. The chute is hinged at the rear and when raised allows free access to the rotor and flails. The height of discharge when delivering at the rear is 10ft 9in, and at the side 11ft.

The multi-purpose screw jack, which can be seen in the illustration we reproduce, has three separate functions. Clamped to the harvester drawbar, it supports the machine and facilitates coupling and uncoupling, and when the harvester is in work, it acts as an adjustable control of the minimum cutting height. The land wheels of the harvester can be set at three different levels as an extra cutting height adjustment, and to raise the wheels clear of the ground for setting, the jack is fitted into a side-clamp.

The statically and dynamically balanced two-bladed rotor has twenty flail cutters and gives a 40in cut. An adjustable sole plate enables the length of chop and degree of laceration to be varied. The complete unit weighs 15 cwt.

[Reply Card No. E5262]

INDUSTRIAL NEWS

British Employers' Confederation

Lord McCorquodale of Newton, P.C., president of the British Employers' Confederation, in presenting the annual report for adoption at the Confederation's annual general meeting held last week in Birmingham, recalled that at the annual general meeting last year both Sir William Garrett and he had expressed concern about the possibility of a fresh upward movement of labour costs upsetting the stability in the general price level which had been enjoyed in the previous two years. Although industrial production had risen during the past year, wage increases in many basic industries and services, including coal and transport, have been greater than could be absorbed without an increase in prices. The retail prices index had been moving upwards in recent months, the president said, and the danger was more real than it had been since the autumn of 1957 that prices and wages would again chase each other upward in a way which, sooner or later, would require the Government to take fresh drastic measures to preserve not only the internal but also the external position of the pound sterling.

The Confederation was engaged in discussions with the T.U.C., the president said, about some of the issues concerning relations between employers and trade unions with particular reference to unofficial strikes. It had entered into these discussions, he added, in the hope that it would be possible to improve the situation without changes in the law and without departing from traditional methods which depended on a proper sense of responsibility being shown by representations of both employers and workpeople. A heavy responsibility lies upon employers, he continued, to cultivate good relations with their workpeople so that the efforts of those who would disrupt them were less likely to succeed.

Iron and Steel—Profits and Costs

At the annual general meeting of the British Iron and Steel Federation held in London last week Mr. C. R. Wheeler, the president, said though 1960 was by no means without its problems and anxieties, especially in the closing months, considered as a whole it was a year of buoyant expansion.

Although the marked increase in output last year was naturally accompanied by an increase in total steelmaking profits, the average profit margin, Mr. Wheeler said, changed little as against the previous year ; and, indeed, he added, profit margins came under considerable pressure from rising costs in the closing months of the year. Such a trend must cause the industry considerable concern, Mr. Wheeler said, faced as it was with a development bill of over £200,000,000 this year. With this in mind, the Federation had been discussing with the Iron and Steel Board both the adequacy of the rate of profit currently allowed in their prices and the £22,000,000 of additional costs which have fallen on the industry recently or were firmly in prospect.

In this context, Mr. Wheeler continued, the coal price increase of September, 1960, warranted special mention. This was a serious blow to the industry and in the immediate sense, it may add some £19,000,000 to its costs, either directly or by provoking consequential price increases elsewhere. Mr. Wheeler also drew attention to one event of 1960 which, he said, threatened further cost increases in the future, namely the introduction of the Rating and Valuation Bill. The Federation hoped, he said, that satisfactory amendments may yet be secured during the Bill's passage through Parliament, particularly with regard to the wholly inequitable rating of process plant as well as buildings, which bears especially heavily on the iron and steel industry.

Machine Tools

The figures of deliveries, orders on hand and estimated net new orders for metalworking machine tools for December, 1960, have been issued by the Machine Tool Trades Association. Figures are based on returns from firms accounting for about 75 per cent of total deliveries and include estimates for smaller firms making only quarterly or annual returns.

The demand for machine tools during 1960 was extremely heavy, the Association says. Net new orders received by manufacturers in the United Kingdom were valued at more than £140 million, which was 79 per cent more than in 1959. At the end of December the value of orders on hand was 89 per cent higher than a year earlier. The order book at the end of December showed orders valued at £81,629,000 for the home market, compared with £40,151,000 in December, 1959, and £23,753,000 for the export markets compared with £15,740,000 a year earlier. The value of deliveries of machine tools increased, though slowly, after allowing for seasonal variations, and in the fourth quarter of 1960 was 21 per cent more than a year earlier ; in the year as a whole the increase was 19 per cent. Export deliveries increased rather faster than deliveries to the home market, the Association says, and in the fourth quarter the value was 26 per cent higher than a year earlier, making the increase for the year as a whole 30 per cent.

Overseas Trade

The latest figures issued by the Board of Trade show that United Kingdom exports in February were valued at £297 million, imports at £353 million and re-exports at £11,200,000. After adjustment for normal seasonal variation, the Board says, United Kingdom exports were £307 million and imports £383 million.

Exports increased by 5½ per cent and imports declined by 1 per cent between the last three months, December-February, and the previous three months, September-November, but these comparisons are affected by the London dock strike in that the figures for the last three months include some imports and exports that would otherwise have taken place in the previous three months. This accounts for a substantial part of the increase in exports. Nevertheless, the Board points out, in the last six months as a whole, exports were at a rate 5 per cent above that of the previous three months, June–August, when they were at the lowest level reached in 1960. Similarly, the Board says, the 1 per cent decline in imports in the last three months understates the extent of the fall. Since mid-1960 the underlying trend of exports has clearly been upwards. The rise in imports, which continued through most of 1960, had come to an end by the final quarter, and the latest figures suggest a downward movement.

The increase in exports of engineering products between September–November and December–February was about 10 per cent, seasonally adjusted, and although the dock strike probably affected this figure, the underlying increase, the Board states, must have been substantial. The largest and the sharpest increase was in machinery other than electric, although there were also substantial increases in the export of electric machinery and appliances, commercial vehicles and scientific instruments. There was no sign of recovery in car exports, the Board says, exports in the last three months being less than in the previous three months, and 46 per cent less than a year earlier. Aircraft exports showed an increase, but deliveries of ships for export fell.

Industrial Relations

The Rt. Hon. John Hare, Minister of Labour, addressed the Conservative Trade Unionists' Conference in London last week. After reviewing some of the recent developments in the field of industrial relations, Mr. Hare went on to say that he had recently embarked on an investigation at national level, with the National Joint Advisory Council, of a wide range of problems in industry which affected relations between management and workers. With the agreement of the Council, he said, he was setting up a committee of experts which he hoped would lead to fresh interest and progress in the training of supervisors, and, no less important, of potential supervisors. The Council was also considering arrangements which could be made in industry to deal with the problems of redundancy, and he hoped an agreed document, which would set down practices which had been found by many employers to work well in dealing with their problems, would very soon be published.

Commenting on the joint talks at which a special attempt was being made to improve labour management relations in the motor industry, Mr. Hare said that he had been most impressed by the positive and constructive attitudes which had been adapted to the talks by leaders of the motor industry and representatives of the Confederation of Shipbuilding and Engineering Unions. There had been full and frank discussion, he said, covering a wide range of problems, including the selection and training of supervisors and shop stewards, consultation, demarcation difficulties, work study and disputes procedures. A number of constructive ideas had been put forward. At the wish of both sides Mr. Hare has taken the chair at these meetings. This high level discussion of the problem of a particular industry was a new departure in the work of the Ministry of Labour, Mr. Hare pointed out, but he hoped that it would have fruitful results.

PERSONAL AND BUSINESS

Appointments

MR. JOHN ROBERTS has been appointed Midland area representative for Weldcraft, Ltd.

MR. A. W. GIRLING has been appointed to the board of Aveling-Barford, Ltd., as director in charge of production.

C. A. PARSONS AND CO., Ltd., announces that Mr. E. C. Rippon has been co-opted as a director of the company.

MR. J. CARLE has been appointed managing director of George Richards and Co., Ltd., a member of the Stavely group of companies.

GULF EASTERN COMPANY announces the appointment of Mr. R. B. Hoffman and Mr. C. D. Read as vice-presidents of the company.

MR. C. W. HAMILTON has succeeded the late Mr. E. L. Raworth as chairman of McCall and Co. (Sheffield) Ltd., and McCalls Macalloy, Ltd., and continues as managing director.

LONDON MIDLAND REGION, BRITISH RAILWAYS, has announced the appointment of Mr. M. Harbottle as civil engineer's new works officer, Euston.

THE IRON AND STEEL INSTITUTE announces that Dr. Howard Biers, F.I.M., and Dr. T. P. Colclough, .R.I.C., F.I.M., have been elected honorary vice-residents.

THE DELTA GROUP have appointed Mr. A. F. Thomas and Mr. D. J. W. Dolton to the boards of directors of Sperryn and Co., Ltd., and C. H. Edwards, Ltd.

LANG PNEUMATIC, Ltd., states that on being elected to the board and appointed general manager, Mr. G. E. Jowitt is retiring from the position as secretary with effect from April 1. He will be succeeded as secretary by Mr. G. H. Oxborrow.

FIRTH CLEVELAND INSTRUMENTS, Ltd., states that Mr. F. R. Allen, an executive director, is now in charge of the company's sales engineering department. Mr. W. J. Megson has joined the company as instrument representative for the north-east area of England.

MR. E. F. CHOPPEN will rejoin the board of directors of Esso Petroleum Company, Ltd., on April 4, 1961, after completing a year's assignment with Standard Oil Company (New Jersey) in New York. Mr. L. B. Johnson has also been appointed a director of the company with effect from that date.

MR. PETER W. HOTSON has been appointed area representative by Frederick Parker, Ltd., to cover Northumberland, Cumberland, Westmorland, Durham and the North Riding of Yorkshire. He succeeds Mr. E. Hargreaves, who has retired after thirty years' service with Parker's.

THE ELECTRICITY BOARD FOR NORTHERN IRELAND has appointed Mr. C. M. Stoupe, M.I.E.E., formerly deputy chief engineer, to be general manager and chief engineer as from April 1, following the retirement of Mr. T. G. Christie. Mr. Christie will, for a limited period from April 1, be engaged on special duties for the Board.

BARCLAY, CURLE AND CO., LTD., announces that its deputy general manager at Elderslie Dockyard, Scotstoun, Glasgow, W.4, Mr. John Campbell, retires to-day after thirty-five years with the company. He has been succeeded at Elderslie Dockyard by Mr. Malcom McLean, works manager at Barclay Curle's Clydeside repair works at Govan.

MR. S. P. ESCOTT, managing director of Portsmouth Aviation, Ltd., has been appointed chairman in succession to Lieut.-Colonel G. B. Clarke, who has retired from the chair due to pressure of other duties, but continues to serve on the board. Mr. N. H. Nash, A.F.R.Ae.S., technical director, and Mr. F. Wilkinson, works director, will be joint managing directors.

MR. J. H. PITCHFORD, M.I.Mech.E., managing and joint technical director of Ricardo and Co., Engineers (1927), Ltd., was recently inducted at Geneva as President of the Federation Internationale des Societies des Ingenieurs des Techniques de l'Automobile (F.I.S.I.T.A.) in succession to Monsieur Fernand Picard, Regie Nationale des Usines Renault of France.

G.K.N. STEEL COMPANY, Ltd., has announced the appointment of Mr. C. F. Pagnamenta as a director. He remains as secretary of the company. G.K.N. Steel Company, Ltd., also announces the following appointments as local directors : Mr. A. T. Harris, chief engineer of Brymbo Steel Works ; to Guest Keen Iron and Steel Works board, Mr. T. Dennison, group development officer.

THE GENERAL POST OFFICE states that Mr. A. W. C. Ryland, at present director of establishments and organisation, has been appointed director of inland telecommunications, in succession to Mr. F. I. Ray who retires to-day. Mr. H. A. Daniels, at present assistant secretary in the radio services department, has been appointed director of establishments and organisation.

LLOYD'S REGISTER OF SHIPPING states that Mr. J. H. Milton, principal surveyor in charge of the engineering investigation department of the chief engineer surveyor's staff, has been promoted to succeed the late Mr. R. Shaw as principal engineer surveyor for the North-East Coast area. Mr. Milton will be succeeded as head of the engineering investigation department by Mr. B. Hildrew, with the rank of principal surveyor.

THE COMPOFLEX GROUP states that the following reorganisation of its sales staff will take effect from April 1. Mr. H. J. Bergin, previously southern sales manager of Compoflex Company, Ltd., has been appointed to the newly-created post of marketing manager. He will operate from the Group's head office at Paddockhall Road, Haywards Heath, Sussex. Mr. F. Balmforth, previously northern sales manager, has been appointed home sales manager, based at Huddersfield Road, Oldham, Lancs. He will be responsible for the Compoflex U.K. sales force, warehouses, &c. Mr. A. R. Davies, who was export manager, becomes the Group's Australian representative, with headquarters at Melbourne, and has been succeeded as export manager by Mr. P. Christensen. Mr. D. Reece continues as sales manager of Rollo-Hardy and Co., Ltd.

Business Announcements

MR. J. H. BREBNER retires to-day from his post as public relations adviser to the British Transport Commission.

MR. J. W. MARTIN, director and sales manager of Whessoe, Ltd., retires to-day after thirty-seven years with the company.

H. AND A. ENGINEERING (LONDON), Ltd., states that its new address is 8, Oldfields Trading Estate, Sutton By-Pass, Sutton, Surrey (telephone, Burgh Heath 6944).

THE FEDERATION OF BRITISH RUBBER AND ALLIED MANUFACTURERS has moved its offices to 19-20, Berners Street, London, W.1. The telephone numbers, Museum 2671 and 0268, remain unchanged.

EDWARDS HIGH VACUUM, Ltd., Crawley, Sussex, has been appointed sole United Kingdom and British Commonwealth agent for the new "Reciprotor" combined vacuum/pressure pump manufactured in Denmark.

IMPERIAL CHEMICAL INDUSTRIES, Ltd., Imperial Chemical House, Millbank, London, S.W.1, is to spend more than £6,000,000 on modernising a large section of its Billingham factory during the next two years.

PRESS AND SHEAR MACHINERY COMPANY, Ltd., 172-178, Victoria Road, Acton, London, W.3, has been appointed sole distributor and licensee for the range of up-stroking hydraulic press brakes manufactured by Promecam SA., 63, Rue de Strasbourg, Saint Denis, Seine, France.

THE BIRMINGHAM TOOL AND GAUGE COMPANY, Ltd., Soho Hill, Birmingham, 19, has signed an agreement with Madison Industries, Inc., of Providence 4, Rhode Island, U.S.A., for the manufacture and distribution of its range of trepanning, boring and reaming tools, automatic recessing tools, gun drills, boring bars, Microller burnishing tools and other tubing equipment.

LANSING BAGNALL, Ltd., announces that preliminary plans have been completed for the manufacture and distribution of Lansing Bagnall materials handling trucks in the United States by the Towmotor Corporation of Cleveland, Ohio. Under a reciprocal arrangement, Towmotor products will be manufactured at the Lansing Bagnall factory at Basingstoke, Hants, for marketing in Europe, Africa and Asia.

BIRFIELD, Ltd., 20, Hill Street, London, W.1, wish it to be known that the voluntary liquidation of Bodmin Tools, Ltd. (formerly Birfield Tools, Ltd.), is entirely a matter of internal re-organisation. All creditors have been or will be paid in full. This re-organisation in no way affects the activities of the present Birfield Tools, Ltd., which will continue to trade from its new factory at Old Bromford Lane, Stechford, Birmingham.

DAVY AND UNITED ENGINEERING COMPANY, Ltd., states that consequent upon the merger of the former Davy-United and Power-Gas Groups, to form the new Davy-Ashmore Group, as from April 1 public relations for the Davy-Ashmore Group as a whole will be conducted from Davy-Ashmore, Ltd., Darnall Works, Sheffield, 9, under the control of Mr. F. R. Smith, group public relations officer. General publicity matters for the group will be handled from Davy-Ashmore, Ltd., P.O. Box 21, Stockton-on-Tees under the control of Mr. H. Hopwood, group publicity manager.

THE BRITISH PETROLEUM COMPANY, Ltd., and THE RIO TINTO COMPANY, Ltd., announce that they have reached an agreement whereby British Petroleum will acquire from Kern Oil Company, Ltd., a wholly-owned subsidiary of Rio Tinto, all the issued shares of Kern Trinidad Oilfields, Ltd., Kern Oil California, Ltd., and St. Helens Petroleum Corporation together with Kern's shareholding in Devon-Palmer Oils, Ltd. Kern Trinidad Oilfields, Kern Oil California and St. Helens Petroleum are all wholly-owned subsidiaries of Kern with properties in Trinidad and the United States of America. Devon-Palmer Oils' properties are in Canada.

Contracts

BIRLEC-EFCO (MELTING), Ltd., is to supply Birlefco electric arc furnaces to the English Steel Corporation, Ltd., and Clyde Alloy Steel Works, Ltd. Two furnaces will be built for English Steel, each of 100 tons nominal capacity, and one for Clyde Alloy, also of 100 tons nominal capacity.

JOHN HOWARD AND CO., Ltd., has been awarded a contract by the Admiralty for the construction of a N.A.T.O. ammunition storage depot at Glen Douglas, Scotland. The work is expected to take three years to complete and the cost will be between £2,000,000 and £3,000,000.

EDMUND NUTTALL, SONS AND CO. (LONDON), Ltd., has been awarded a contract for dredging in the port of Haifa, Israel, by the Haifa Harbour Authority. The contract, which involves dredging some 1,500,000 cubic metres of sand from the harbour, is of an approximate value of £300,000.

R. AND U. DEMPSTER, Ltd., Gas Plant Works, Newton Heath, Manchester, 10, one of the licensees recently appointed by the patentees, the North Western Gas Board and the Clayton Analine Company, to market the Stretford sulphur extraction process, has received an order for a plant to deal with approximately 11,000,000 cubic feet of refinery gas per day. The plant will be delivered and erected at Antwerp, and is the first operating on this process to be ordered.

TARMAC CIVIL ENGINEERING, Ltd., a member of the Tarmac Group, has been awarded a contract worth approximately £600,000 for the first three phases of civil engineering work in the reconstruction of the Steel, Peech and Tozer Works of the United Steel Companies, Ltd. The work involves the construction of foundations for two new arc furnaces, a casting bay, scrap pen and a furnace cellar. Other work includes site levelling and demolition, and the construction of a transformer house, roads, bridges and drainage.

PLOWRIGHT BROTHERS, Ltd., has received orders from the Butterley Company, Ltd., of Ripley, Derbyshire, for modifications and extensions to the "Aglite" lightweight aggregate plant at its Salterwood Works. The contracts, valued at over £100,000, include clay preparation and handling equipment, crushing, handling and storage of the sintered product and structural steel buildings as well as all the necessary electrical equipment and modifications to part of the existing electrics. Henry Pooley (Consulting Engineers) of 36, Victoria Street, London, are the consultants for the sinter handling equipment for the Butterley Company.

THE GENERAL ELECTRIC COMPANY, Ltd., of England, is to build four 350MW turbo-alternators for the Tilbury "B" generating station of the Central Electricity Generating Board. This order is worth more than £8,000,000. Each set will incorporate a tandem-compound 3000 r.p.m. turbine, having operating conditions, at the stopvalve, of 2300 lb per square inch gauge and 1050 deg. Fah., with reheat to 1050 deg. Fah. and exhausting at a vacuum of 28·9in Hg. Power will be generated at 20kV by alternators equipped with water-cooled stator windings and direct-hydrogen-cooled rotor windings. The first two sets are due to be commissioned in 1965 and the next two in 1966.

CONTINENTAL AFFAIRS

by Our Continental Editor

Long-Welded Railway Track in the Netherlands

MOST of the subsoil in the western, low-lying part of the Netherlands consists of alluvia and peaty strata of poor loadbearing quality. It is not surprising, therefore, that problems caused by subsidence play an important role in the maintenance of the Dutch railways, in particular, as the embankments themselves are generally constructed of the same unsatisfactory material. Since subsidence takes place unevenly, it is necessary periodically to lift long sections of track and renew the ballast.

This procedure has to be carried out as economically as possible, hence gravel is used in place of crushed stone or blast-furnace slag which would require to be imported. Unfortunately, gravel offers but a low resistance to lateral or longitudinal movements of the track.

For some years past certain parts of branch lines have been converted to long-welded track by thermite-welding the joints. This has been confined to curves where the speed of trains is reduced. Such tracks rest on wooden sleepers and methods have been sought to increase the adhesion of the sleepers in the ballast. In 1954, two experimental tracks were installed, both with wooden sleepers. One had iron shoes attached underneath the ends of the sleepers, the other had sleepers arranged in a zig-zag pattern. Both these tracks proved to be effective, but the second was more economical and easier to maintain.

When considering the adoption of long-welded track on the main lines, the fact must be taken into account that the traffic density is very high, and that practically the only time when the traffic can be interrupted is during the night from Sunday to Monday; at all other times only limited speed restrictions—from 120 km.p.h. to 90 km.p.h.—can be imposed. While the seasonal temperature fluctuations may range from −30 deg to +55 deg. Cent., daily variations of up to 40 deg. Cent. are also encountered. Such conditions not only increase the difficulties of construction but with the weak gravel ballast greatly heighten the risk of buckling.

For these reasons, the Netherlands Railways have been interested for some years in tracks using concrete sleepers. Trials of various designs had shown the French "RS" double-block sleeper—which happened also to be the most economical type—to have the best resistance to lateral displacement. Between 1952 and 1957, some 110,000 of these sleepers were installed in crushed gravel ballast. This represents some 30km of track. For subsidiary track sections, a simpler version was used, with a steel tube connecting the two concrete sections of the sleeper. These tubes were held in place with cotter pins in steel sockets embedded in the concrete. About 109,000 sleepers were installed; for economy's sake, only every second or third pair of blocks was connected by a tubular tie.

The promising experience with zig-zag wooden sleepers led to the adoption of this idea for concrete sleepers.

The new "zig-zag" (or ZZ) track (Fig. 1) consists of long-welded rails resting on concrete sleeper blocks spaced 69 cm apart, the rows of blocks on the two rails of each track being staggered. The blocks weigh 100 kg apiece and have a bearing area of 2500 square centimetres, equal to 7300 square centimetres per metre of track which is about twice the effective bearing area of wooden sleepers. Lateral resistance is increased by giving the blocks a waisted shape, and an inward slope of 1 in 20 corresponding to the same slope of the rail itself.

The rails are attached to the sleepers by spring clips fitted to hooks, and their position on the sleepers is fixed by angle irons. Both the hooks and angle irons are bonded to the concrete by a synthetic glue. This, in addition to being a convenient method of attachment provides a good degree of electrical insulation, which is very convenient for automatic track control.

Each of the concrete blocks is joined to its diagonally opposite numbers by two steel tubes

Fig. 1—The trussed construction of the "zig-zag" track, with concrete sleepers connected by tubular diagonals, gives great resistance to buckling, and thereby offsets the low resistance of the gravel ballast widely used in the Netherlands

which are held in a trapezoidal recess in the concrete by screwing down a cast iron wedge.

One of the advantages of the design is that the track can be transported piecemeal, and installed in place of the old track in stages, without the need to interrupt the traffic. The procedure was first adopted in November, 1958, on the Amsterdam–Amersfoort line where a 1500m long track with 2000m radius and 65mm superelevation was installed. Since then, this track has given satisfactory service under traffic conditions of ninety-four trains per hour and train speeds of 120km.p.h.

The installation procedure was first to replace the old 24m rails by long rails which at first were 480m long and later on 720m. This replacement was carried out at night during periods of slack traffic. An expansion section at the beginning of the long-welded track avoided the occurrence of temperature stresses. After fixing the position and gauge distance with setting rods, the existing wooden sleepers were removed in the daytime one by one and replaced by the concrete sleeper blocks and tubular ties. The setting rods were then taken out. The expansion joint was then moved at night to the next section where the procedure was repeated. Meanwhile, in the section already equipped with concrete sleepers the rails were placed on rollers, heated to between 18 and 22 deg. Cent., and refastened. Subsequently any necessary levelling was carried out, followed by accurate setting of the gauge and alignment of the track. Setting of th gauge was carried out by adjusting of the tubular ties. This method is stated to have permitted a degree of precision not previously attainable.

Tests have been carried out in the laboratory of British Railways, Western Region, on behalf of the Netherlands Railways, with a view to comparing the "zig-zag" track with different kinds of track used in Great Britain. Also tested were the static and dynamic creep resistance, the torsional resistance of the fastenings, the lateral moment of resistance, the ballast resistance, and the safety against buckling.

These tests were carried out with rails of the kind used on British Railways, and specially adapted D-E fastenings.

Static Creep Resistance.—The static resistance to creep of this fastening is not characteristic of other designs of concrete sleeper fastening but is more reminiscent of timber sleeper assemblies. Gradual relative movement of the rail and sleeper began when the applied force reached 250 lb, and after a previous creep of 0·2in, a force of 2600 lb sufficed to maintain a steady movement. The test was performed in a machine consisting of a hydraulic ram on a frame. A short length of rail guided by rollers was pushed against the sleeper which was held by a rocking plate so as to simulate the resistance of the ballast. The force was measured by a proving ring and the displacements by dial gauges.

Torsional Resistance.—On average, the torsional coefficient was found to be considerably

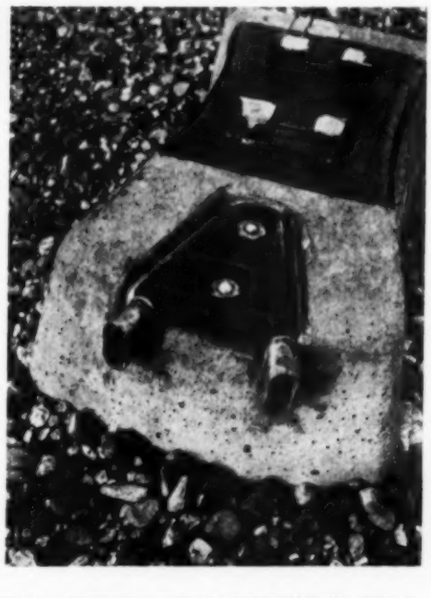


Fig. 2—Alternative method of fastening diagonals by means of clamping plate. The tubes and plate are bedded in synthetic glue

CONTINENTAL AFFAIRS *(continued)*

lower than with previous fastenings tested. In this test a short length of rail was mounted on a sleeper which was rigidly clamped to the testing machine. Hydraulic force was applied in a horizontal direction at right angles to the rail, and acting through the centroid of the rail section.

Lateral Moment of Resistance.—Due to the fact that the track forms a truss, the resistance to lateral deflection was much higher than for any previous track. A lateral load of 1200 lb caused an elastic deflection of 0·1in which disappeared almost entirely with the release of the load. To obtain a 0·5in deflection, a load of 4300 lb was required as compared with 1200 lb for tracks with concrete sleepers used in Great Britain. To carry out this test, a 30ft length of track was supported at either end by virtually frictionless supports, and loaded centrally by a hydraulic ram. The ram force was measured by a proving ring and the deflections at intervals of 5m by dial gauges, both as the load was increased and as it was being reduced. From the graphs of load against deflection, the lateral moment of resistance and the coefficient of elasticity were determined.

Buckling.—In this test a 120ft length of track was subjected to an axial load developed through an increase of temperature of the rails. The track rails were anchored at each end to concrete blocks in such a way that horizontal or vertical rotations were prevented but not longitudinal movement. The latter was controlled by four tie bars, two on each side of the track, which were connected to crossheads butting on to the rail ends. Hydraulic jacks were incorporated between the tie bars and crossheads so that any longitudinal movement could be taken up. The amount of such movement and lateral deflections were measured by dial gauges. Electric heating elements fitted with reflectors were used to heat the rails which were equipped with thermometers. An empirical formula for the buckling load was developed.

The test track was placed on the ballast without filling the spaces between sleepers or making shoulders in order to prevent the testing device from being overloaded. Normally, a misalignment is put in after assembly, but as the " zig-zag " track was too stiff for this to be done, the misalignment had to be built in during assembly. In the first test, the misalignment amounted to 2in over a 70ft chord ; no failure was caused by heating the track up to 90 deg. Cent. when the compressive load amounted to approximately 290 tonnes. In another test a misalignment of 4in led to explosive buckling at a temperature of 51 deg. Cent., equal to 166 tonnes compression. It appeared that where the track yie.ded the tubes slipped out of the housings in the concrete, or the bolts securing the wedges were ripped out.

Although with normal cross sleeper track there is the danger that it may buckle vertically before the horizontal buckling limit is reached, this danger is less with concrete sleepers because of their greater weight. On " zig-zag " track the reduction of ballast resistance, should vertical deformation occur, is not so critical due to the great lateral stability of the track independently of the ballast. It was found that the only vertical movement which occurred was the result of the sleepers moving laterally on the ballast which was sloped at an inclination of 1 in 20 ; one set of sleepers moving down, and the other up.

Dynamic Creep.—Secondary resistance to creep was determined for three assemblies of the " D–E " fastening and although all showed a steady deterioration during the fifty hour test, in no case did the resistance drop to less than 1500 lb. Tests were conducted on a single half sleeper—base-plate fastening assembly, with a short rail slightly over 2ft 7in long, the normal sleeper spacing. This assembly was supported by a roller bearing plate which in turn was supported by four torsion bars. The load-deflection characteristics of these bars could be altered to represent the elasticity of the bed ; they were normally set to 60 tons per inch deflection. Movements were imparted to the rail by two hydraulic rams connected to it at either end through two strain gauge cells and universal connections. Two cams used to control the rams were driven by a hydraulic motor. Each of their revolutions produced movements of the rail equivalent to those which would result from a 0–6–0 locomotive with 10-ton wheel loads covering a distance of sixteen sleepers. A ten-hour period of continuous running at 200 r.p.m. of the cams was equivalent to forty locomotives per day over a five-year period. No account was taken of hammerblow. Each test occupied fifty hours, thus representing twenty-five years of track life under locomotive loading only. At ten-hourly intervals, the assembly was tested for static and dynamic creep.

Insulation.—No tests were undertaken for determining the electrical insulation of the " zig-zag " track.

Ballast Resistance.—Tests were carried out with uncompacted ballast under the sleepers only, without boxing or shoulders. It appeared that under these conditions the lateral resistance of

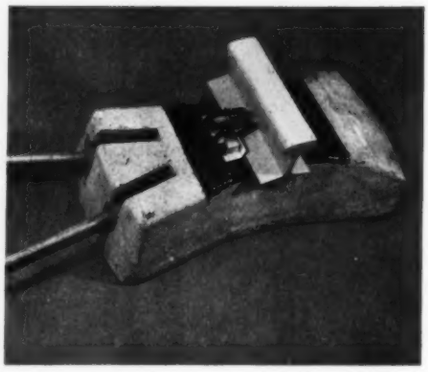


Fig. 3—Experiments are continuing with a simple method for attaching the diagonals by bonding them into slots in the concrete

two of the concrete block sleepers was lower than that of one British Railways standard type " F " sleeper. The weight of the two concrete blocks was 450 lb compared with 600 lb for one type " F " sleeper. Making allowance for the difference in weight, the " zig-zag " sleeper turned out to have the higher resistance which could be further increased by boxing and iorming shoulders.

Tests were carried out with a dummy assembly of six sleepers, normally spaced and rigidly connected to steel channels which could be hydraulically loaded by means of two synchronised rams.

Conclusions.—The low values for the static and dynamic creep resistance and for the torsional resistance of the fastenings, were ascribed to the fact that the spring clips did not fit sufficiently accurately the rail section employed in the tests. The high buckling strength of the trussed track was clearly brought out.

The cost of " zig-zag " track is claimed to be only 90 per cent of that of track with wooden sleepers, and although it is slightly more costly to install on balance it compares favourably with the old method.

Further Developments.—Instead of clamping the diagonal tubes to the concrete blocks by means of wedges, as shown in Figs. 1 and 2, it appears possible to bond them into slots in the concrete by means of a synthetic bonding agent (Fig. 3). This would constitute a further simplification and saving on cost.

Between 1958 and the end of the current year, some fifteen sections of main line totalling 68 km will have been changed over to " zig-zag " track. Another fifteen sections, totalling 15·5 km, will have been equipped with BB (buis-blok) track. This form of track has sleepers consisting of two concrete blocks joined by one glued-in tubular steel cross member.

Strain Gauge Equipment

An automatic selector and a twenty-point panel for use with its existing strain gauge apparatus " Model 1516 " has been introduced by Brüel & Kjær, Nærum, Denmark (agent : B & K Laboratories, Limited, 4, Tilney Street, London, W.1.). The selector consists of a fifty-position switch, and sufficient terminals and R and C balancing components for the connection of ten full or half strain gauge bridges. Where there are more than ten gauges this has been catered for by the twenty-point panel. Thus, in order to obtain fifty measuring points, one selector switch and two panels are required. The switch can be operated either by hand, or automatically by an electro-mechanical drive from a transistorised multivibrator. Measuring intervals of 0·5, one, two or four seconds are available, and the consecutive switching steps are readily observed on an illuminated scale which is subdivided into five sections of ten steps. An incorporated relay circuit allows to scan an arbitrary selected number of points, and a fast-return then causes the switch to recommence the sequence by swiftly passing through the points not connected for measurements. Where a synchronous paper recording is required, the selector can be remotely controlled from a switch on the level recorder. A means of marking the recorder paper on each complete revolution of the switch is available.

In the bridge balancing units, a ten-turn wire-wound potentiometer is used which ensures high ohmic resolution, giving quick and easy balancing even with a high-resistance strain gauge.

Cybernetics Congress

The Third International Congress on Cybernetics, organised by the International Association for Cybernetics, will be held at Namur from September 11 to 15, 1961. The programme will be arranged in five sections : " Principles and Methods of Cybernetics " ; " Semantic Machines " ; " Automation : Technical Aspects " ; " Automation : Economical and Social Aspects " ; and " Cybernetics and Life." Those wishing to present a paper to the Congress are invited to inform the Secretary of the Association of their intention, stating the title of their contribution. Fees for attendance have been fixed at B.Fr. 200 for members, and B.Fr.400 for others. No fee will be charged to the authors of papers. Further information may be obtained from the Secretary of the " Association Internationale de Cybernétique, A.S.B.L.," rue Basse-Marcelle, 13, Namur, Belgium.

Guillaume Centenary

Celebrations have taken place in Switzerland of the centenary of the birth of Charles-Edouard Guillaume (1861–1938), a pioneer of the watch-making industry. After studying at Neuchâtel and Zurich, Guillaume, in 1883, joined the International Bureau of Weights and Measures at Sèvres of which he later became the director. One of his most important contributions was the discovery of the alloys known as " Invar " and " Elinvar " which on account of their zero coefficient of thermal expansion became very important in the construction of watches and clocks. Besides many other recognitions of his achievements, Guillaume received the Nobel Prize for Physics.

THE AMERICAN SCENE

By Our American Editor

Hydro-Electric Power Project with Pumped Storage at Niagara Falls

No. II—(*Concluded from page 478, March 27, 1961*)

The Niagara Power Project of the State of New York was formally dedicated and commenced commercial power generation on February 10. When ultimately completed in 1963, the scheme will comprise twenty-five turbo-generators capable of producing a total of 2190MW, making it the largest hydro-electric power station in the western world. The principal features of the scheme are the Robert Moses Niagara power station, with thirteen 150MW generators, the Tuscarora storage reservoir of 60,000 acre-feet and power station, with twelve 20MW reversible pump turbines, an intake structure above the Niagara Falls, a 4000ft long canal connecting the two power stations, and miscellaneous canal and conduit structures.

Related Improvements

THE Niagara Power Project has sparked (and in part paid for) the cost of a tremendous park, parkway and redevelopment programme, which at last has removed the eyesores adjacent to the Falls and upper river and opened the entire natural resources to public use and enjoyment. The programme included a new scenic parkway running for 10 miles along the river front, new and enlarged parks, additional bridges, an expressway, the relocation of railway tracks and yards, grade crossing eliminations, new and improved facilities for sightseeing and the opening of new areas for residential and industrial development. The power development financed substantial incidental improvements and also paid the U.S. share of the cost of remedial works designed to preserve Niagara Falls.

The Niagara Parkway is a wide modern landscaped parkway running along the Niagara River. It is under construction from the Grand Island bridge upstream of the Falls to the new international Lewiston-Queenston bridge, 6 miles below the Falls. Above the Falls, the land for this parkway was created using excavated materials, thus adding many acres of new land to the park system. This parkway will afford magnificent views of both the upper river and the gorge below the Falls. Prospect Park at the Niagara Reservation has been completely rebuilt and construction has been finished on a new American Rapids bridge to Goat Island and also on a 4000ft section of bordering parkway. A spectacular observation and elevator tower being constructed by the Niagara Frontier State Park Commission as part of the joint programme will be opened in the spring.

The parkway will have walks, overlooks and other recreation facilities at various points along the river. It will cross the power station on a two-level structure and connect directly with the new Lewiston-Queenston bridge. Land for the extension of Niagara Parkway north to Fort Niagara and Lake Ontario is now being acquired as part of the State park system. Construction will follow in 1962 and 1963. Eventually this parkway will connect with the westerly extension of Lake Ontario Parkway.

The Lewiston-Queenston bridge is under way, and the Niagara Falls Bridge Commission has successfully floated a 20,000,000 dollar bond issue. The bridge completion date is May 30, 1962.

The Niagara Express way connecting the North Grand Island bridge with the new International bridge is now being built with Federal and State funds. Rights of way are being acquired and contracts at the bridge approach have been let by the New York State Department of Public Works. The Expressway is also scheduled for completion on May 30, 1962.

In the vicinity of the Tuscarora reservoir the Authority will build a public park to be called Reservoir Park, consisting of 143 acres to be operated by the Niagara Frontier State Park Commission. Considerable strips along the route of the conduits must be retained by the Authority for transmission lines. This land cannot be built upon or used for active recreation,

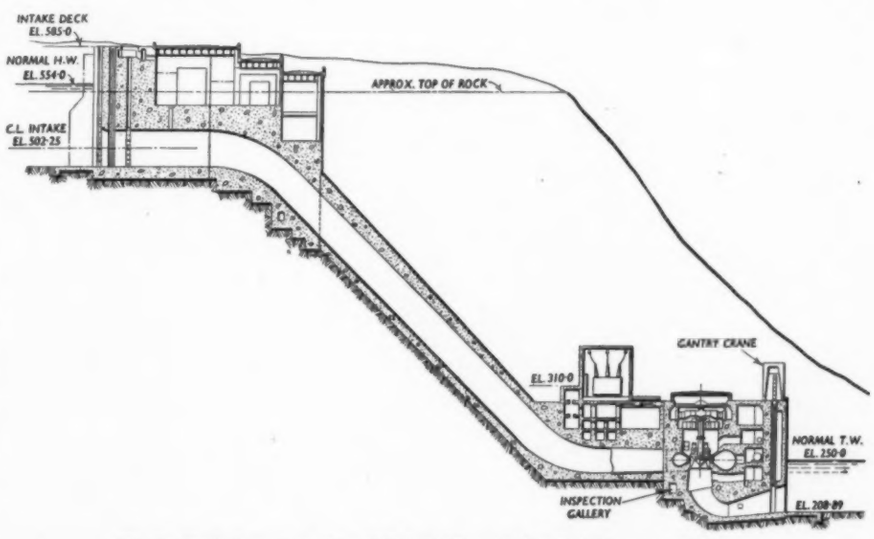


Fig. 7—Typical cross section of Robert Moses hydro-electric power station

THE AMERICAN SCENE *(Continued)*

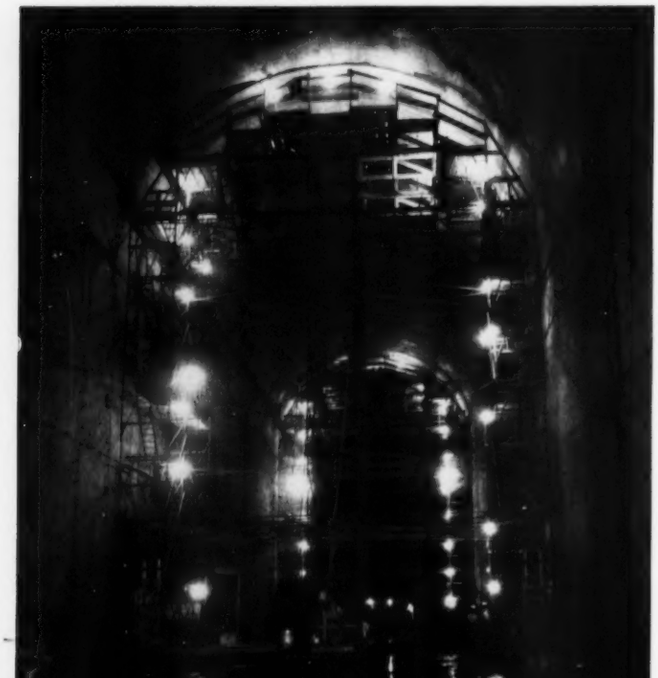


Fig. 8—Interior of conduit, showing finishing of concrete surfaces with the use of "Jumbo" work platforms

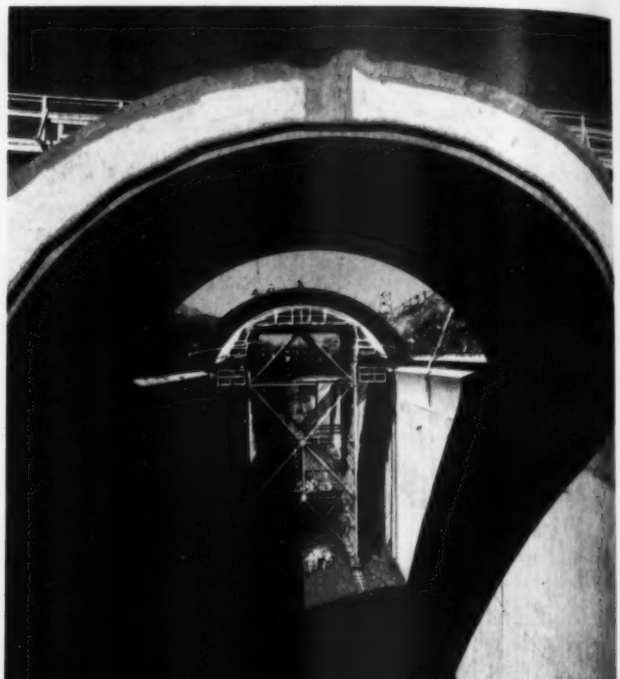


Fig. 9—Construction of reinforced concrete arches for the No. 2 conduit of the waterways

but will be graded, seeded and maintained in good condition by the Authority.

Robert Moses Niagara Power Plant

The Robert Moses Niagara Power Plant will have thirteen Francis turbines, each rated 200,000 h.p. at 300ft net head, driving Westinghouse generators, each rated at 150MW. They will be driven by water fed through penstocks 24ft in diameter, under an hydraulic head averaging 305ft. With a rating of 150MW each, the generators are the largest and most powerful ever made by an American manufacturer. Each generator weighs 1094 tons and is 40ft in diameter. The rotor is driven at 120 r.p.m. by a shaft weighing 56 tons and measuring more than 4ft in diameter. Power will be generated at 13·8kV, three-phase, 60 c/s, and stepped up by Ferranti 180MVA transformers in the power station to 115kV and 230kV. The power station is 1840ft long, 389ft high, including foundation, and 580ft wide, from the face of the intake to the final outlet in the river.

Tuscarora Reservoir and Power Station

The 60,000 acre-feet storage reservoir in the town of Lewiston was constructed by building about 6½ miles of dykes, using material excavated from the power canal. The dykes average 55ft in height, are 260ft wide at the base and 40ft wide at the top. The reservoir power station is situated at the opposite end of the Power Canal, where water from the conduits empties into the canal, immediately adjoining the easterly end of the reservoir.

From an engineering point of view the Tuscarora pumped storage scheme is probably the most interesting aspect of the entire Niagara Power Project. The recent development of large, reversible pump-turbines, such as the 83,000 h.p. Hiwassee pump-turbine of the Tennessee Valley Authority, led to the decision to use reversible pump-turbines also on both sides of the Niagara River for this purpose. The Hydro-Electric Power Commission of Ontario has already installed six vertical reversible pump-turbines in the Sir Adam Beck pumped storage station, rated to generate 40,500 h.p. under 85ft net head. Each is an English Electric

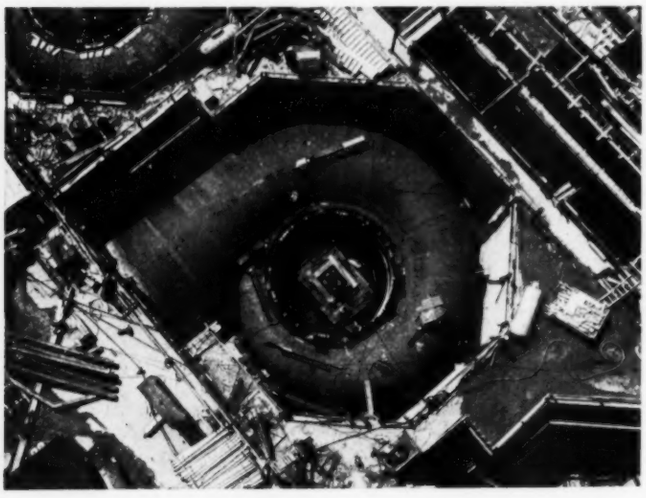


Fig. 10—Completed spiral case of 200,000 h.p. Francis turbine installed at Robert Moses power station

Fig. 11—General view of the 115kV switchyard section situated halfway between the two power stations

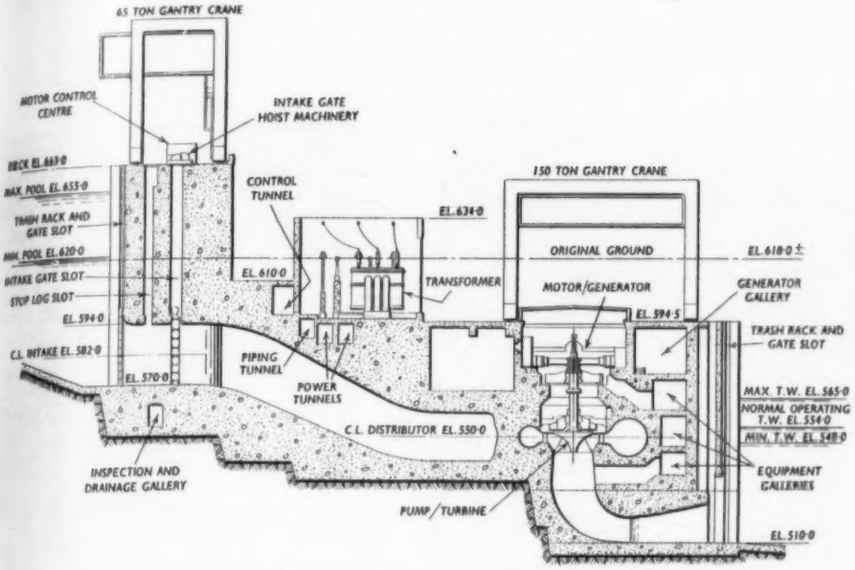


Fig. 12—Typical cross section of Tuscarora pumping-generating station

diagonal-flow propeller-type unit with adjustable blades, known as a Deriaz pump-turbine. The Power Authority of the State of New York is installing twelve vertical reversible Francis-type pump-turbines, each rated to generate 28,000 h.p. under 75ft net head at the Tuscarora pumping-generating station. The net head for turbine operation will vary between 53ft and 95ft. Six of these machines will be supplied by Allis-Chalmers and six by S. Morgan Smith.

Each pump-turbine is rated to pump 3400 cusecs of water against a dynamic head of 85ft. The dynamic pumping head will vary between 57ft and 99ft. The pump-turbines will run at 112·5 r.p.m. in a clockwise direction as turbines and counter-clockwise for pumping. Each unit will have a welded steel spiral case with an 18ft diameter inlet. Due to its large size, the spiral-case segments will be welded to each other and to the stay ring during the assembly at the site.

Each of the runners will be more than 17ft in diameter and will weigh approximately 51 tons. Each runner will have six buckets, and the lower portion of the buckets will be overlaid with stainless steel for protection against pitting. Six of the runners will be carbon steel castings with the buckets cast integral with the crown and runner band. The lower portion of these buckets will be stainless steel segments welded to the carbon steel buckets. The main shaft will be a 28in diameter steel forging with a coupling flange bolted to the runner crown and an upper coupling flange bolted to the generator motor shaft. A stainless steel sleeve is provided on the shaft where it passes through the packing box on the head cover. The turbine bearing is a babbitted unit lubricated with oil by means of motor-driven pumps. There are twenty wicket gates made of cast carbon steel controlled by two servo-motors.

A model of these pump-turbines was tested in the Allis-Chalmers hydraulic laboratory. Performance tests and cavitation tests for pumping and turbine operation were made on a pump-turbine model to the complete satisfaction of the consulting engineers for the Power Authority of the State of New York. The ratio of model to prototype was 1 to 13·73. The efficiency was stepped up from the model test by the Moody formula. The calculated hydraulic thrust plus the weight of the runner and shaft was 330,000 lb. The estimated runaway speed at 95ft maximum head is 198 r.p.m.

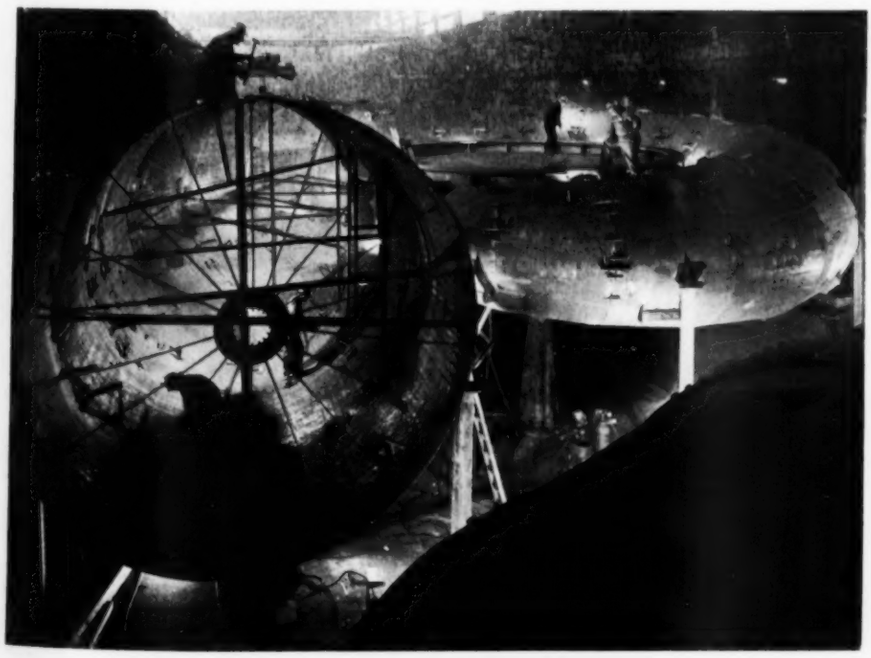


Fig. 13—Shop erection of welded steel spiral cases for the 28,000 h.p. pump/turbines at the Allis-Chalmers works at Milwaukee

Intake Structure

Situated 2¼ miles above the Falls are two intakes and two intake gate structures. Each intake is 700ft long and has forty-eight slotted openings, the tops of which are 13ft to 26ft below the river surface. Adjacent to the intakes, at the entrance to each of the two conduits, is a gate structure about 55ft wide by nearly 100ft high. Each gate structure contains a 49ft by 68ft vertical lift gate, which can be lowered to prevent water from entering the conduits when and if it becomes necessary to inspect the conduits or make repairs.

Two parallel, reinforced concrete conduits, each 46ft wide and 66ft high, extend northward for 4¼ miles from the intakes to the forebay-afterbay of the Tuscarora reservoir power station and the power canal. Much of the excavation for the conduits was in solid rock, and in places the cuts were 150ft deep. After being constructed, they were covered by earth and the ground was landscaped. The combined capacity of the conduits is sufficient to carry the full U.S. share of Niagara River water available for power generation.

The power canal, running east and west between the two power stations, carries water from the outlet of the conduits and water

Fig. 14—Downstream view from completed intake structure, showing stop logs and intake gate beyond

released from the reservoir to the main power station. It is 4000ft long, 500ft wide and 110ft deep.

Miscellaneous Structures

A switchyard is situated on 35 acres of land south of the power canal, about midway between the two power stations. The equipment includes thirty-three oil circuit breakers, each capable of safely interrupting 10,000MVA of power under short circuit conditions.

The Niagara power development is linked with its sister project, the St. Lawrence Power Project, by means of a 300 mile tie-line which will permit power to be transmitted in either direction. The tie-line will increase the firm power capacity of each project, because normally water flow at the St. Lawrence project is highest during the summer—precisely the time when the treaty reduces the water available for power production at Niagara Falls. The tie-line includes two 345kV circuits between Niagara and Rochester and one 345kV circuit from Rochester to a point north of Utica. There the line ties into an existing 230kV system owned by the Niagara Mohawk Power Corporation, which, in turn, connects with the Authority's 230kV Adirondack transmission line extending

THE AMERICAN SCENE *(continued)*

Fig. 15—View looking downstream from the transition section of the intake structure showing arch construction at the intake gate

70 miles south from the St. Lawrence project. The 345kV circuits will be the highest-voltage lines in the eastern part of the United States. Heretofore, 230kV was the maximum voltage in use in this region.

On top of the south abutment of the main power station will be an attractive, glass-enclosed building with facilities for visitors. Surrounding the topmost of three levels on three sides will be an open cantilever observation deck affording dramatic views of the large plant, of water rushing from the turbines and of the entire Niagara River as it flows through the gorge. Inside the 120ft by 150ft building will be various exhibits and a large mural painting by Thomas Hart Benton. Mr. Benton's mural will be 7ft high and 20ft in width and will depict Father Louis Hennepin viewing Niagara Falls. Father Hennepin, a Recollect missionary, was the first white man to write at length of the power and beauty of the Falls. The exhibits will include a diorama, 9ft high and 19ft long, showing the gorge and a cutaway view of the power plant, animated to reveal water falling through the penstocks and spinning the turbines. Another exhibit will be a 20ft by 30ft terrain map of the area showing the Falls, upper and lower river, the escarpment and gorge and the various parts of the power project.

The Niagara Power Project was designed and built by the Power Authority of the State of New York, with Robert Moses acting as chairman and William S. Chapin as general manager and chief engineer. Messrs. Uhl, Hall and Rich, of Boston, Massachusetts, were the General Engineering Consultants for the scheme. The principal civil engineering contracts were held by the Merritt-Chapman and Scott Corporation, the Channel Constructors Joint Venture, the Balf-Savin-Winkelman Joint Venture, the Gull Contracting Company, L. G. De Felice and Sons, and the Arundel-Dixon-Hunkin-Conkey Joint Venture. The major equipment supply contracts were held by the Westinghouse Electric Corporation, the Allis-Chalmers Manufacturing Company, the S. Morgan Smith Company, the Baldwin-Lima-Hamilton Corporation, the Newport News Shipbuilding and Drydock Company, the Chicago Bridge and Iron Company, and two foreign concerns—Ferranti, Ltd., and Brown Boveri.

Radio Aerial Corona Rings

The strings of aerial insulators at the Machias Bay, Maine, transmitting station of the U.S. Naval Communications System are being equipped with pairs of anti-corona rings fabricated in two sizes from Republic Steel stainless steel tubing to give the needed non-magnetic properties, strength and corrosion resistance to salt sea air. The rings form a safe gradient for 400,000V so that transmitter power is not dissipated in corona losses or arcing.

The larger of each pair of corona rings has a 20ft diameter mouth pyramided to a steel plate at the other end by six 15ft legs. The smaller of the two rings is similar in construction with a 15ft diameter mouth. The open end of the rings is made from 4½in o.d., 0·165in wall stainless steel tubing in three sections. The rings were designed by the Lapp Insulator Company, Inc., of LeRoy, N.Y. and supplied as part of their insulator assemblies. Three attachment fittings to which turnbuckles and legs are attached are welded to each section of the tubular circle. The end of each section is flared for the insertion of a stainless steel plug used to connect one section of the circle to the next.

A ring is mounted at each end of every insulator string, requiring some ninety-six corona rings in all. The mouth ends of the rings face each other on the insulator string and are fastened to the insulator links by six shielded barrel turnbuckles. Generally, the station will operate with an input power of 2MW. The power equipment will be able to generate 12MW so that de-icing may be carried on simultaneously with the powerful v.l.f. transmission.

Active Repeater Satellite

A communications satellite containing an active repeater, and intended for operation in an equatorial orbit, has been built by the Hughes Aircraft Company. The satellite is 29in in diameter and weighs only 32 lb. In a stationary orbit, 22,000 miles above the equator, positioned directly above the mouth of the Amazon River, it would be visible to ground communications stations throughout most of North and South America, Western Europe and the western half of Africa. The satellite has been designed for launching by a "Scout" rocket. In place of a complex attitude control system, it would be stabilised by a spinning motion imparted during launch, and its precise position and orientation in orbit would be adjusted by two nitrogen jets. Power for the communications repeater is provided by 2700 solar cells.

Mobile Remote Manipulator

A manipulator for use in areas too dangerous for human operators that simulates the human being's ability to move about has been developed by Hughes Aircraft Company, Culver City, California. The mobile robot is called a "Mobot," and is restrained only by a triaxial cable carrying power and multiplex signals. The two arms are "double-jointed" at "shoulder," "elbow" and "wrist," each joint being controlled by a separate switch. The clasp of the hands is effected by air-inflated cushions, also controlled by switches. The two "eyes," closed circuit television cameras, are mounted on "tentacles." The whole robot moves on small wheels. The operator uses switches to select the desired movement and pedals to regulate speed.

The "Mobot" engaged in a chemical experiment; its grip is by inflated pads in the "hands"

BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each

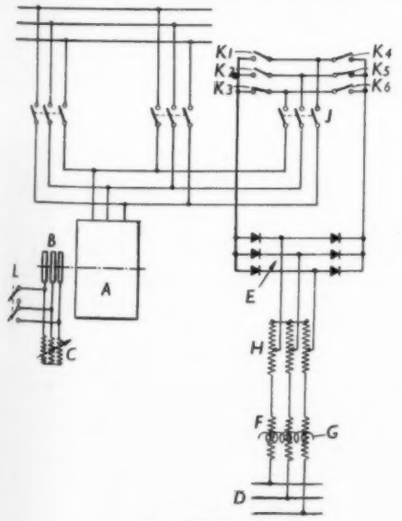
ELECTRICAL ENGINEERING

862,323. August 29, 1957.—SEQUENCE CONTROL APPARATUS, Associated Electrical Industries, Ltd., 33 Grosvenor Place, London, S.W.1. (*Inventors : Anthony Hall and John David Stanley Heraud.*)

In many types of sequence control it is necessary to vary the sequence. As an example, in controlling the settings of the screw-down motors of a steel rolling mill it is necessary to adjust the screw-down setting each time an ingot is rolled. Twenty or more such settings may be required for one ingot, and other operations such as tilting the ingot by manipulators must also be controlled. For different ingots or conditions of rolling a number of different schedules or programmes of settings and operations will be required and the main object of the invention is to provide sequence control apparatus in which it is possible to select a number of different sequences. According to a preferred arrangement a number of programmes of operation instructions are interspaced in a recurring sequence along a tape. Successive switch contacts of the switching device which moves the tape through a reading head are associated with the different programmes in a similar sequence, and selector switching apparatus is arranged to mark the contacts associated with a selected programme at which the reading head is to be effective. Thus, whilst the switching device moves step by step, a fresh operation is performed only when the device reaches a contact associated with the selected programme. The tape can be a punched tape and the switching device can be a uniselector operated electro-mechanically to move step by step. The reading head can be arranged to produce control signals, which signals may conveniently operate servo apparatus to carry out the required operation. The servo apparatus may comprise means for deriving an error signal by comparing the control signal with the position (or other state) of the equipment to be controlled, and adjust the equipment in accordance with the error signal. Whilst the invention is more particularly described as employing electro-mechanical switching, other forms of switching apparatus, e.g. electronic, may be employed.—*March* 8, 1961.

862,295. March 27, 1958.—CONTROL ARRANGEMENTS FOR ELECTRIC MOTORS, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. (*Inventor : Erich Siegfried Friedlander.*)

Control arrangements for creep speed control of induction motors employing low frequency a.c. excitation are known, but if control of the motor by dynamic braking is required, an a.c. commutator machine is necessary for providing the excitation current. One object of the present invention is to provide an improved control arrangement in which this disadvantage is avoided. Referring to the



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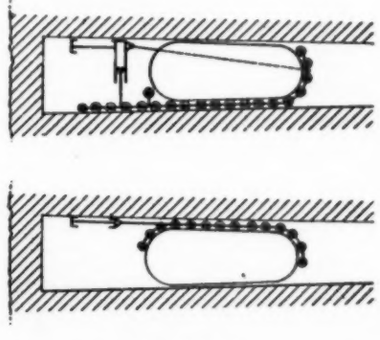
drawing, a wound rotor induction motor *A* has stator windings (not shown) which are arranged to be connected to an a.c. supply for forward or reverse driving. The secondary windings are connected through slip rings *B* to a liquid resistance controller *C*. The primary windings are also arranged to be connected to an excitation current supply for dynamic braking of the motor, this supply being obtained from an auxiliary a.c. supply *D* feeding a rectifier *E* through a saturable reactor *F* having a control winding *G*, and a transformer *H*. The auxiliary supply may be fed by a petrol engine driven generator. Connection of the primary windings to the excitation supply is effected by a three-pole contactor *J* and a set of six single-pole contactors *K*1 to *K*6. The contactors *K* are arranged to be closed in pairs so that at any one time, with the contactor *J* closed, the direct current terminals of the rectifier are connected across two of the primary windings. Moreover the contactors *K* are arranged to be operated in cyclical sequence, whereby pulsating current having a frequency corresponding to the frequency of operation of the contactors is fed to the primary windings. For dynamic braking of the motor, the contactor *J* would be closed and direct current would be fed to two of the primary windings via the contactors *K*3 and *K*5, as shown in the drawing. In order to obtain creep and speed control of the motor, or in the event of failure of the main power supply, the contactor *J* would be closed and the contactors would be operated in cyclical sequence, in one sense or the other, so that pulsating current is fed to the primary windings which would be equivalent to feeding a low frequency three phase a.c. to these windings. During such operation it is necessary that the resistance *C* in the rotor circuit should be kept to a minimum, and for this purpose contactors *L* are provided which short circuit the slip rings when low frequency excitation is employed. By introducing d.c. into the rotor circuit, it is possible to operate the motor as a synchronous motor when pulsating excitation current is fed to the primary windings. This synchronises the movement of the motor with the operation of the contactors *K*. By this method the creep speed can be made independent of load, and reduced to arbitrary low values, and very accurate decking can be obtained when the motor is used to drive a mine winder.—*March* 8, 1961.

MINING EQUIPMENT

862,210. April 18, 1957.—MINE ROOF SUPPORTS, Karl Balthasar, Bergwerk, Penzberg, Upper Bavaria, Germany.

A mine roof support in accordance with this invention comprises supporting elements each consisting of an elastic bolster of rubber or plastic filled with gas or liquid to absorb the loading pressure over a large area and capable of rolling between the floor and the roof of a mine while under full load. In the specification five different forms or embodiments of the invention are shown diagrammatically and we reproduce by way of example. Bolsters with roller tracks are located in the gallery between the floor and the roof. The bolsters of elastic, impermeable, pressure- and wear-resistant rubber or plastic material can be inflated with air under pressure. The rock load of the roof will then be transmitted



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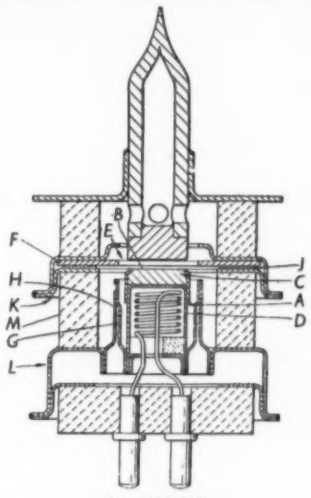
over large areas by the bolsters and the roller tracks to the floor ; the magnitude of the supporting force being determined by the area of the bearing surface and the pressure of the bolster filling or inflating medium. In a propped gallery or heading, the bolsters are located with their longitudinal axes parallel to the working face, along the front of the heading, and support the roof on the gobbing or packing side. For then the forward motion of the bolsters are pressed over or under their associated roller tracks or auxiliary bolsters between the floor and the roof rolling about their longitudinal axes, towards the working face. They are thus in positive, frictional contact with the roof and the floor. No slipping or dragging can take place, since the sliding friction is an appreciable multiple of the rolling friction and the indentation pressure. This ensures that the bolsters acting in the place of props can be rolled forward, under the full rock pressure between the roof and the floor. The rolling of the bolsters is performed by pushing or traction means described in detail.—*March* 1, 1961.

ELECTRONICS

862,448. June 18, 1958.—THERMIONIC VALVES, The M–O Valve Company, Ltd., Brook Green, Hammersmith, London, W.6. (*Inventor : Arthur Everard Widdowson.*)

This invention relates to thermionic valves, particularly those in which it is desirable that the spacing between the control grid electrode wires and the cathode should remain substantially constant, since variations in this spacing may give rise to variations in the characteristics of the valve. One embodiment of the invention is described with reference to a thermionic triode valve adapted to operate at ambient temperatures of up to 400 deg. Cent., and to form part of a microwave system intended for operation at frequencies of up to 7000 Mc/s. Referring to the



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drawing, the valve includes an indirectly heated cathode *A*, the electron emissive surface *B* of which is formed by one main face of a disc *C* of porous tungsten impregnated with alkaline earth metal compounds. The disc is mounted on the outer surface of the base of a molybdenum cup *D*. The grid electrode *E* of the valve includes a metal frame *F* having an aperture centrally formed in it, and fine parallel wires which are brazed to one main face of the frame and extend across the aperture. In operation of the valve, the ambient temperature and the operating temperature of the cathode may vary considerably thus causing appreciable expansion or contraction of the various parts of the valve. The support for the electron-emissive surface *B* of the cathode can be considered as comprising four parts. The first part comprises the disc *C* and the cup *D* ; the second part comprises the support member *G* ; the third part comprises the support member *H*, and the fourth part comprises the shim *J*, the annular members *K* and *L*, and the ceramic tube *M*. These parts are joined together successively between the cathode and the control grid. It will be appreciated that expansion of each of the first and third parts would tend to urge the electron-emissive surface *B* towards the grid electrode *E* and that expansion of each of the second and fourth parts would tend to urge the electron-emissive surface away from the grid electrode ; the valve is so designed that in operation variations in the expansions or contractions of the above mentioned parts in directions parallel to the axis of the envelope tend to cancel one another out so that the spacing between the grid electrode and the cathode remains substantially constant.—*March* 8, 1961

Catalogues and Brochures

W. C. HOLMES AND CO., Ltd., P.O. Box No. B.7, Turnbridge, Huddersfield.—Publication No. 85, "Holmes-Connersville Positive Air Blowers, type RBS."

B. W. VALVE COMPANY, Ltd., 140, Granville Street, Birmingham, 1.—Four-page leaflet describing the "Winn Flexiseat" pivoted disc valve for water, air, oil, gas, &c.

FAWCETT PRESTON AND CO., Ltd., Bromborough, Cheshire.—Publication No. FP118 describing the Greer-Mercier hydropneumatic accumulator, manufactured under licence from Greer Hydraulics, Ltd.

WELWYN ELECTRIC, Ltd., Bedlington, Northumberland.—Brochure describing "Metox" miniature oxide resistors and the "total excursion" method of classification which has been introduced for guidance in selecting components which will be within the tolerable resistance range for their expected working life.

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., Rugby.—Publication 4103-1, "'Numeritol' Continuous Numerical Control of Machine Tools," describing continuous numerical control in two or three dimensions using ¼in wide magnetic tape as a medium of information to the machine tool. The publication is illustrated with schematic diagrams and photographs and describes the principles of preparing the control data, and converting them from planning sheet form into the magnetic tape which, on passing through the "Numeritol" controller, provides the signals for the servo control of the tool.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Tues., April 4.—SOUTH EAST LONDON BRANCH: Eltham Green School, Queenscroft Road, Eltham, S.E.9, "Domestic Appliances," Miss Lois Stevens, 7.45 p.m. ★ WEST LONDON BRANCH: "White Hart," 49, Kings Road, Chelsea, London, S.W.3, "Colour Photography," 7.45 p.m. ★ READING AND DISTRICTS BRANCH: College of Further Education, Bourne Road, Maidenhead, "Current Trends in Winding Wire Manufacture," A. J. Taylor, 7.30 p.m.

Wed., April 5.—HALIFAX BRANCH: Crown Hotel, Horton Street, Halifax, "Carpet Design," F. W. Evans, 7.45 p.m. ★ NORTH LONDON BRANCH: Wood Green Civic Centre, Town Hall, Wood Green, N.22, Films, 8 p.m. ★ MANCHESTER BRANCH: Engineers Club, Albert Square, Manchester, "Modern Temperature Control Systems," C. Cowell, 7.15 p.m. ★ PRESTON BRANCH: R.A.F.A. Club, East View, Preston, "Engineering Aspects of 33kV Cable Installations," 7.30 p.m.

Thurs., April 6.—BRIGHTON, HOVE AND DISTRICT BRANCH: New Imperial Hotel, First Avenue, Hove, Sussex, "Electrical Application to the Paper Industry," A. Castle, 7.30 p.m.

Fri., April 7.—LIVERPOOL AND DISTRICT BRANCH: Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, Films, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., April 5.—SCOTTISH SECTION: Department of Natural Philosophy, The University, Drummond Street, Edinburgh, Annual General Meeting, 7 p.m.

Thurs., April 6.—NORTH WESTERN SECTION: Reynolds Hall, College of Technology, Manchester, "Plant Investigation and Control Using Digital Techniques," K. J. McCarthy, 7 p.m. ★ TELEVISION GROUP: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, Discussion on "Transistorised Television Receivers," 6 p.m.

COVENTRY ENGINEERING SOCIETY

Thurs., April 13.—Social Club, Coventry Victor Motor Company, Ltd., Ford Street, Coventry, "Some Modern Methods of Producing Close Tolerance Light Alloy Castings," Mr. Pendleton, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Wed., April 5.—EDINBURGH CENTRE: Y.M.C.A. Social Room, 14, South St. Andrew Street, Edinburgh, Annual General Meeting, 6.15 p.m. ★ NEWCASTLE UPON TYNE CENTRE: Room 87, The Percy Building, King's College, Queen Victoria Road, Newcastle upon Tyne, 1, "The Design Criteria for Integrated Lighting in Buildings," D. Phillips, 6.15 p.m.

Thurs., April 6.—Nottingham Centre Electricity Centre, Carrington Street, Nottingham, "Ship Lighting," A. E. Fothergill, 6 p.m.

Mon., April 10.—SHEFFIELD CENTRE: Grand Hotel, Sheffield, Annual General Meeting, and Lighting Forum, 6.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Thurs., April 13.—BEDS. AND HERTS. SECTION: W. H. Allen, Sons and Co., Ltd., Bedford, Annual General Meeting, and Quiz, "Fault and Cure," 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., April 10.—MERSEYSIDE AND NORTH WESTERN SECTION: Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Materials for Advanced Steam Conditions and their Influence on Operation of Turbines and Boilers," H. E. C. Hims and S. H. Frederick, 6 p.m. ★ WEST OF ENGLAND SECTION: Small Engineering Lecture Theatre, The University, University Walk, Bristol, 8, "Details and Operating Data of Recent A.C. Installations," A. N. Savage, 7.30 p.m.

Tues., April 11.—Memorial Building, 76, Mark Lane, London, E.C.3, "Experience with Hardened and Ground Gearing in the Royal Canadian Navy," D. K. Nicholson, 5.30 p.m.

INSTITUTE OF METALS

Tues., April 4.—OXFORD LOCAL SECTION: Cadena Café, Cornmarket Street, Oxford, Annual General Meeting, and "Ductile Fracture," R. W. K. Honeycombe, 7.15 p.m.

Thurs., April 6.—BIRMINGHAM LOCAL SECTION: College of Technology, Gosta Green, Birmingham, Annual General Meeting, 6.30 p.m. ★ LONDON LOCAL SECTION: 17, Belgrave Square, London, S.W.1, Annual General Meeting, and "Physical Methods of Analysis for Major Alloying Constituents," K. M. Bills, 6 p.m.

INSTITUTE OF PETROLEUM

Wed., April 5.—61, New Cavendish Street, London, W.1. "Airborne Techniques in Petroleum Exploration," W. Domzalski, 5.30 p.m.

INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

Wed. to Fri., April 5 to 7.—Brunel College of Technology, Acton, London, W.3, Symposium on "Electrical Contacts," to be held in collaboration with the Institution of Electrical Engineers.

INSTITUTE OF REFRIGERATION

Thurs., April 6.—Institute of Marine Engineers, Memorial Building, 76, Mark Lane, London, E.C.3., "Results of Practical Experiments on Relative Humidity Control," J. A. Cox, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Wed., April 5.—WESTERN CENTRE: Vineyard Restaurant, Colerne, Annual General Meeting, 7 p.m.

Thurs., April 6.—SOUTH WESTERN GROUP: Queens Hotel, Exeter, Annual General Meeting, 7.30 p.m.

Fri., April 7.—SOUTH WALES CENTRE: Grand Hotel, Cardiff, Annual General Meeting, 7.15 p.m.

Mon., April 10.—MANCHESTER AND DISTRICT CENTRE: Whitworth Room, Second Floor, Engineers' Club, Albert Square, Manchester, Annual General Meeting, 7.30 p.m. ★ SCOTTISH CENTRE: North British Hotel, Edinburgh, "Special Servicing Tools for Heavy Transport Vehicles," J. Blaber, 7.30 p.m.

Tues., April 11.—EASTERN CENTRE: White Hart Hotel, Newmarket, Annual General Meeting 7.30 p.m.

INSTITUTE OF WELDING

Tues., April 11.—LIVERPOOL AND DISTRICT BRANCH: City of Liverpool College of Technology, Byrom Street, Liverpool, 3, Annual General Meeting and Film Show, 7.15 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., April 11.—Society of Chemical Industry, 14, Belgrave Square, London, S.W.1, Joint meeting with the Chemical Engineering Group, "A Systematic Classification of Chemical Processes and Equipment," K. Fischbeck, 6 p.m.

Wed., April 12.—MIDLANDS BRANCH: Chemical Engineering Department, The University, Edgbaston, Birmingham, 15, One-day Symposium on "Materials of Construction," 9.30 a.m. to 5.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Thurs., April 6.—Great George Street, Westminster, London, S.W.1, "River Utilisation and the Preservation of Migratory Fish Life," G. Baxter, 5.30 p.m.

Tues., April 11.—Great George Street, Westminster, London, S.W.1, "Recent Works on the Canal System of B.T.C. and Planning of the Future," V. H. Tripp, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., April 4.—SOUTH-EAST SCOTLAND SUB-CENTRE: Carlton Hotel, Edinburgh, "A General Theory of Depreciation of Engineering Plant," D. Rudd, 7 p.m.

Wed., April 5.—BEDFORDSHIRE SUB-CENTRE: Swan Hotel, Bedford, "An Engineering Project in India," H. E. Knight, 7 p.m. ★ TEES-SIDE SUB-CENTRE: Cleveland Scientific and Technical Institution, Middlesbrough, "Short-Circuit Ratings for Mains Cables," G. S. Buckingham, 6.30 p.m. ★ SOUTHERN CENTRE: Main Hall, College of Technology, Portsmouth, Annual General Meeting, and Third Hunter Memorial Lecture, "The Application of Electronics to the Electricity Supply Industry," J. S. Forrest, 6.30 p.m.

Thurs., April 6.—ORDINARY MEETING: Savoy Place, London, W.C.2, "Technical and Economic Aspects of the Supply of Reactive Power in England and Wales," W. Casson and H. J. Sheppard, 5.30 p.m.

Fri., April 7.—MEDICAL ELECTRONICS DISCUSSION GROUP: Savoy Place, London, W.C.2, Discussion on "The Conversion of Biological Data into Electrical Signals," 6 p.m. ★ SOUTHERN CENTRE: S.E.B. Showrooms, Newport, Isle of Wight, "Subscriber Trunk Dialling," D. A. Barron, to be read by H. E. Francis, 6.30 p.m.

Mon., April 10.—ELECTRONICS AND COMMUNICATIONS SECTION: Savoy Place, London, W.C.2, Discussion on "Applications of Electrical Phenomena at Liquid Helium Temperatures," opened by R. E. Hayes, 5.30 p.m. ★ MERSEY AND NORTH WALES CENTRE: Royal Institution, Colquitt Street, Liverpool, Annual General Meeting, and "The Mechanism of Lightning," J. M. Meek, 6.30 p.m. ★ NORTH-EASTERN MEASUREMENT AND ELECTRONICS GROUP: Rutherford College of Technology, Northumberland Road, Newcastle upon Tyne, Annual General Meeting, and "Some Aspects of the Application of Electronics to Medicine," F. T. Farmer, 6.15 p.m. ★ SOUTH MIDLAND CENTRE: College of Technology, Gosta Green, Birmingham, Joint meeting with the Supply and Utilisation Group, "Development of 'Off Peak Heating' with particular reference to Floor Warming," S. C. Dinenage, 6.30 p.m. ★ WESTERN CENTRE: The University, Bristol, "Speed Changing Induction Motors—Further Developments in Pole-Amplitude Modulation," G. H. Rawcliffe, 6 p.m.

Tues., April 11.—MEASUREMENT AND ELECTRONICS SECTION: Savoy Place, London, W.C.2, "Precision Instruments for Coaxial Line Measurements up to 4 Gc/s," D. Woods, and "The Concept of Equivalent Source, E.M.F. and Equivalent Available Power in Signal-Generator Calibration," D. Woods, 5.30 p.m. ★ EAST MIDLAND CENTRE: Lecture Theatre, Portland Building, The University, Nottingham, "The Power Drive and Control for Jodrell Bank Radio Telescope," O. N. Kington, H. A. Prime, and H. T. Price, 6.30 p.m. ★ NORTH Midland CENTRE: Royal Station Hotel, York, "Some Notes on the Electrical Requirements of General Cargo Docks," E. R. Radway, 7 p.m. ★ NORTH-WESTERN CENTRE: Engineers' Club, Albert Square, Manchester, "The Impulse Strength of Impregnated-Paper Dielectrics as used in High-Voltage Cables," B. F. Salvage and J. A. M. Gibbons, 6.15 p.m. ★ NORTHERN IRELAND CENTRE: Civil Engineering Department, David Keir Building, Queen's University, Stranmillis Road, Belfast 3., "Research on the Performance of High-Voltage Insulators in Polluted Atmospheres," J. S. Forest, P. J. Lambeth and D. F. Oakeshott, 6.30 p.m. ★ SOUTHERN CENTRE: The University, Southampton, "High-Speed Pulse Techniques using Transistors," E. Wolfendale, 6.30 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Mon., April 10.—NORTH STAFFORDSHIRE BRANCH: North Staffordshire Technical College, Stoke-on-Trent, Annual General Meeting, and Film Show, 7.15 p.m.

INSTITUTION OF ENGINEERS-IN-CHARGE

Wed., April 12.—Kent Room, Caxton Hall, London, S.W.1, "Use of Isotopes in Industry," J. P. Frampton, 6.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., April 11.—39, Elmbank Crescent, Glasgow, Annual General Meeting, and "Cavitation Tunnel Tests with Merchant Ship Propellers," H. B. Lindgren, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Fri., April 7.—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Standards of Design for Rural Roads," I. A. Cramm, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Wed., April 5.—SOUTH WALES BRANCH: South Wales Institute of Engineers, Park Place, Cardiff, Symposium on "Automobile Engineering," 2.30 p.m. and 6 p.m. ★ EAST MIDLANDS GRADUATES' SECTION: College of Technology and Commerce, Leicester, Annual General Meeting, and Discussion on "The Future of the Machine Tool Industry," 7.15 p.m.

Thurs., April 6.—YORKSHIRE GRADUATES' SECTION: Grand Hotel, Sheffield, Annual General Meeting, and Films, 6.30 p.m.

Fri. and Sat., April 7 *and* 8.—NORTHERN IRELAND GRADUATES' SECTION: Visit of the Scottish Graduates' Section to Belfast.

Sat., April 8.—EASTERN GRADUATES' BRANCH: Visit to I.C.I. Paints, Stowmarket, 9.30 a.m.

Mon. April 10.—NORTH-EASTERN BRANCH: Neville Hall, Westgate Road, Newcastle upon Tyne, Annual General Meeting, and Repetition of the Nominated Lecture, "The Inspection of the Primary Circuits and Reactor Pressure Vessels of Nuclear Power Plant," H. N. Pemberton and E. Crossley, 6 p.m.

Tues., April 11.—AUTOMOBILE DIVISION: 1, Birdcage Walk, Westminster, London, S.W.1, "Application of the Flash Temperature Concept to Cam and Tappet Wear Problems," A. Dyson and H. Naylor, 6 p.m. ★ NORTH EASTERN BRANCH: Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough, Repetition of the Nominated Lecture, "The Inspection of the Primary Circuits and Reactor Pressure Vessels of Nuclear Power Plant," H. N. Pemberton and E. Crossley, 6 p.m. ★ WESTERN BRANCH: Engineering Laboratories, The University, University Walk, Bristol, "The Potentialities of Accurate Control and Measurement in Engineering Manufacture," J. Loxham, 7 p.m.

INSTITUTION OF PLANT ENGINEERS

Tues., April 4.—PETERBOROUGH BRANCH: White Lion Hotel, Church Street, Peterborough, "Factory Electrical Distribution Systems," J. H. Quick, 7.30 p.m.

Wed., April 5.—EDINBURGH BRANCH: Heriot-Watt College, Chambers Street, Edinburgh, Film, "Highland Journey," 7 p.m. ★ SOUTHERN BRANCH: Grand Hotel, Bournemouth, "Radio Active Isotopes in Industry," 7.30 p.m.

Tues., April 11.—MANCHESTER BRANCH: Manchester Literary and Philosophical Society's Rooms, George Street, Piccadilly, Manchester, "Welding," F. Koenigsberger, 7.15 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Thurs., April 6.—LIVERPOOL GRADUATES' BRANCH: Stork Hotel, Queen's Square, Liverpool, 1, "Principles of Materials Handling," L. J. Hoefkins, 7.30 p.m.

Wed., April 12.—NORTH MIDLANDS REGION: Works Visit to Yorkshire Imperial Metals, Ltd., Stourton, near Leeds, 10.30 a.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Fri., April 7.—GRADUATES' AND STUDENTS' SECTION: Engineering Centre, Stephenson Place, Birmingham, "The Reconstruction of Pershore Lock," G. Botteley, 6.30 p.m. ★ WESTERN COUNTIES BRANCH: Small Lecture Theatre, University Engineering Laboratories, University Walk, Bristol, 8, "Mechanical and Electrical Problems Associated with Multi-Storey Construction," G. K. Medlock, and Film, "The Pirelli Building in Milan," 6.45 p.m.

Wed., April 12.—11, Upper Belgrave Street, London, S.W.1, "Structural Engineering in Nigeria," A. Brimer, 6 p.m.

INSTITUTION OF WATER ENGINEERS

Thurs., April 6.—SOUTH-EASTERN SECTION: Institution of Civil Engineers, Great George Street, London, S.W.1, Annual General Meeting, and "The Organisation of an Engineering Department for Sixteen Re-grouped Water Undertakings," A. Forbes Ilsley, and "Some Considerations on the Siting and Construction of Water Wells," G. R. S. Stow, 2.15 p.m.

JUNIOR INSTITUTION OF ENGINEERS

Wed., April 5.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Words of an Engineer," W. K. V. Gale, 7 p.m.

Fri., April 7.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Films, 7 p.m.

Mon., April 10.—SHEFFIELD AND DISTRICT SECTION: Livesey Clegg House, 44, Union Street, Sheffield, 1, "Cars I Have Owned," T. F. Bailey, 7.30 p.m.

NEWCOMEN SOCIETY

Wed., April 5.—Science Museum, London, S.W.7, "The Windmills of Derbyshire, Leicestershire and Nottinghamshire: Part I, Post Mills," P. H. J. Baker and Rex Wailes, 5.30 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., April 7.—Mining Institute, Newcastle upon Tyne, "Oil Firing with particular reference to Marine Application, G. B. Gray, 6.15 p.m.

PIPELINE INDUSTRIES GUILD

Tues., April 11.—Tudor Room, Caxton Hall, London, S.W.1, One-Day Symposium on "Economics of Pipelines," 9.30 a.m. and Annual General Meeting, 6.30 p.m.

RAILWAY DEVELOPMENT ASSOCIATION

Thurs., April 6.—Lancaster Room, Caxton Hall, Westminster, London, S.W.1, "The Case for Railways," 7.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Thurs., April 6.—WEST OF ENGLAND BRANCH: New School of Engineering, The University, Bristol, "Ready Mixed Concrete," V. S. Wigmore, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Mon., April 10.—HISTORICAL GROUP: Lecture Theatre, 4, Hamilton Place, London, W.1, Discussion on "A Quiz on Little Known Early Aircraft," 7 p.m.

Tues., April 11.—Lecture Theatre, 4, Hamilton Place, London, W.1, "Direct Electrical Power Generation by Thermal and Chemical Means," M. W. Thring, 7 p.m.

Wed., April 12.—GRADUATES' AND STUDENTS' SECTION: Lecture Theatre, 4, Hamilton Place, London, W.1, "Man Powered Flight—Progress to Date," B. S. Shenstone, 7.30 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., April 10.—ORDINARY GENERAL MEETING—12, Great George Street, Westminster, London, S.W.1, "Recent Rating Decisions," D. Widdicombe, 5.45 p.m.

SOCIETY OF ENGINEERS

Mon., April 10.—Geological Society, Burlington House, London, W.1, "The Use of Electric Light and Heat in Horticulture," A. E. Canham, 5 p.m.

SOCIETY OF ENVIRONMENTAL ENGINEERS

Wed., April 12.—Imperial College, Exhibition Road, London, S.W.7, "Climatic and High Vacuum Environmental Test Chambers," V. A. Austin and Mr. Adamson, 6 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Fri., April 7.—Northampton College of Advanced Technology, St. John Street, London, E.C.1, Meeting and Exhibition, "Aids to Training and Education in Automatic Control," 10.30 a.m.

WOMEN'S ENGINEERING SOCIETY

Wed., April 12.—LONDON BRANCH: "Hope House," 45, Great Peter Street, Westminster, London, S.W.1, "Road Research," Miss Sabey, 7 p.m.